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Managing Intermountain Rangelands

—Improvement of Range and Wildlife Habitats

Proceedings of Symposia:
September 15-17, 1981, Twin Falls, Idaho
June 22-24, 1982, Elko, Nevada

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Compilers:

STEPHEN B. MONSEN, Botanist / Biologist, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah.

NANCY SHAW, Botanist, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah.

FOREWORD

Range and wildlife resources are important components of western wildlands. Their value and use continue to gain importance. Consequently, areas must be maintained and managed to gain maximum benefits. Various range and wildland sites have been altered by past uses, resulting in changes of plant composition and a reduction in herbage production and wildlife habitat. Weeds now dominate some areas. Soil losses and disruption to watershed systems have diminished the productivity of some important areas.

Recent advances in revegetation and management systems provide better means to improve many depleted wildlands. The identification of the different subspecies of big sagebrush (*Artemisia tridentata*) has facilitated the development of a habitat typing system for this extensive shrubland. The classification system can be used to determine the distribution and areas of occurrence of species associated with this shrub type. The classified subunits can also be used to determine the site potential and to identify range conditions and departure from climax conditions.

Long-term ecological studies of various vegetal communities, including both grazed and protected sites, have documented the response of individual species. Range and wildlife habitat improvement projects established within the past 60 years provide a history of growth responses and successional adjustments and compatability of introduced and native species. Such information helps determine if areas require remedial treatment and what methods could be employed.

Wildland plantings have been hampered by the lack of seed and plant materials of native species. Seeds of various species are collected in sizable quantities from localized areas, but lack of satisfactory seed standards and marketing guidelines has weakened the sale of quality seeds. Recent selections of grasses, broadleaf herbs, and shrubs have provided strains and ecotypes that are specifically adapted to vegetative conditions and soil types. Of particular importance has been the development of plants that are adapted to arid sites. In addition, seed germination and seedbed requirements have been studied for some principal species. Although data are not available for all species, planting systems have been improved to reduce weedy competition and promote seed germination and survival.

Methods and equipment designed to separately seed slower developing species from more aggressive and rapidly growing species have successfully allowed a mixed composition of species. Interseeders have also been developed to plant select species in established plant communities without fully disrupting the existing species.

As knowledge of range and wildlife improvement practices is more fully developed, both preventive and remedial measures can better be developed. It is anticipated this proceedings will serve these purposes.

ACKNOWLEDGMENTS

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Section 1. Principles of Wildland Restoration

MANAGEMENT IMPLICATIONS ASSOCIATED WITH LAND STRATIFICATION AND HABITAT TYPING

Ronald K. Tew

ABSTRACT: The Boise National Forest is following land systems inventory procedures to identify resource values and management constraints. Habitat-typing concepts are used to refine the inventory data and provide additional interpretations on land systems units. Several levels of inventory are used to meet planning needs.

INTRODUCTION

Land management planning is currently being done on National Forest System lands as required by the National Forest Management Act of 1976. Broad inventories, together with site-specific evaluations, provide the basic data for preparing plans and for making critical land management decisions. The site-specific information is also used extensively in preparing environmental assessments and in selecting areas to be improved.

Much of the data required is being collected through land systems inventories (Wertz and Arnold 1972; Bailey 1980). Habitat types (units of land that are capable of producing similar climax vegetation) are used to refine inventory units by recognizing vegetation types that are indicative of an integrated moisture and temperature regime.

Although nine levels of land systems inventory are recognized by Bailey (1980), only three levels will be discussed here. The most inclusive of these three levels will be referred to as "zones." Zones are broad units of land with similar geologic structure, landform, and climate. Within zones, "landtype associations" are recognized on the basis of landform, soils, geology, and climate. "Landtypes" are identified within the associations. They provide more site-specific information on landform, soils, and vegetation. Habitat types or groups of habitat types are recognized within any land systems level desired.

All three levels are being used to: (1) Describe the location of resources available for management, (2) improve predictive capabilities in terms of production potentials and limitations imposed on management within sensitive environments, (3) provide a basis for extrapolation of information from one unit of land to another, (4) improve interdisciplinary communication where a common land base has been established, and (5) provide a relatively homogeneous environment that reduces sampling variation.

Ronald K. Tew is Range, Watershed, and Wildlife Officer on the Boise National Forest, USDA, Forest Service, Boise, Idaho.

FOREST STRATIFICATION

The land systems inventory process presented by Wertz and Arnold (1972) provided the original framework for land stratification on the Boise National Forest. Work by Wendt and others (1975) expanded the interpretations and provided a Forest map. Since that time, additional changes have been made using the concepts of Arnold (1975) and Bailey (1980) to obtain a broader frame of reference than just the Boise National Forest.

Bailey's map was used to identify analysis areas for the Forest Service Regional Plan in the Intermountain Region (USDA Forest Service 1981b). The Boise National Forest is located within the Northern Rockies Analysis Area, characterized by the grand-fir-Douglas-fir vegetation types.

Within the Northern Rockies Analysis Area, subsections identified by Arnold (1975) were superimposed on the forest base map. These subsections established differences in basic geologic structure and landform and helped refine analysis areas. The resulting units are the zones previously defined. Landtype associations recognized by Wendt and others (1975) were expanded to provide contiguous units within these zones. The stratification process used in delineating associations was based on five broad geomorphic groupings: (1) Glaciated lands formed on high-elevation landscapes, (2) cryic lands occurring on frost-churned areas at moderately high elevations, (3) fluvial lands formed on landscapes dominantly affected by the erosive action of water, (4) volcanic lands formed on flows and cones, and (5) depositional lands resulting from glacial moraines, outwash materials, and alluvium.

All or portions of 21 zones were established to cover approximately 3 million acres of land. From three to five landtype associations were recognized within each zone. More than 100 landtypes were identified throughout the forest.

GEOLOGY AND SOILS

Granitic (quartz monzonite and granodiorite) parent materials of the Idaho Batholith cover approximately 85 percent of the Boise National Forest. Soils are sandy and often shallow to moderately deep over fractured decomposed bedrock. Clayton and Arnold (1972) have described the differences in bedrock characteristics in terms of structure, texture, weathering, and fracturing qualities which affect the type of soil being developed.

Basalt flows are common on the southern end of the forest where deeply cut canyons overshadow the streams. A limited acreage of structurally controlled basalt lands with west-facing dip slopes occurs on the west-central portion of the forest. In the basalt parent materials, soils are often shallow, cobbly clay-loams, although some sites have moderately deep to deep soils that are very productive.

MANAGEMENT IMPLICATIONS

Discussion of management implications associated with land systems inventory and habitat typing is limited to production potentials, sampling intensities, extrapolation of data, sedimentation and mass wasting problems, and implementation of watershed and forage improvement projects.

Range Forage Production

Forage production has been measured on range allotments for many years. In the past, information has been collected by range type (sagebrush/grass, dry meadow, etc.) without correlation to soils and habitat types. As a result, sampling variability has been greater than desired.

Because range forage sampling sites were identified on maps, they can now be correlated with mapped land systems units. Also, because range habitat types have been established for Idaho, this concept can be applied to the older inventory information by recognizing key species identified on inventory forms.

With major funding constraints, there will be few opportunities to continue range analysis in the traditional manner, yet production information is still needed to prepare adequate plans for allotment management. To meet this demand, information from approximately 1,300 transects was assembled and analyzed. Production was evaluated by range types on land systems units at various levels of stratification.

Although this type of analysis helped in interpreting production values, there was a real need for further refinement. It was recognized that year-to-year variation was great and that production and species composition varied greatly within range types, which included many habitat types. Also, it was common to only have 1 year of inventory data.

To improve interpretations, information was sorted into habitat types. Herbage production was then summed, using data from 1963 to 1981. Production by habitat type was established for individual species of grasses, forbs, and shrubs together with totals for each of these categories. Forage values were assigned to individual species and total herbage production was adjusted based on differences in species palatability. Using many years of data greatly increased the reliability of production estimates on specific areas identified in the land systems inventory.

Sampling Intensity

Because inventory and sampling is a continuous process, one must decide the proper level of sampling. Previous inventories provide the measure of variation needed to make these estimates. Although the example being used relates to range production, equal use can be made of the homogeneous land units for wildlife studies, soil monitoring programs, timber production estimates, and similar studies.

Using range analysis data, it is possible to determine the coefficient of variation for production studies and relate these values to the number of samples needed to obtain acceptable estimates. The coefficient of variation expresses the sample standard deviation as a fraction of the sample mean and is useful in calculating sample size using the following equation:

$$n = \frac{(t^2)(CV)^2}{E^2} \quad \text{where}$$

n = the number of samples needed.
t = a tabular value from the student's t-distribution based on a specified confidence level and on sample size.
CV = the coefficient of variation.
E = the percent variation from the true mean value that is acceptable (expressed as a decimal).

A quick evaluation of the equation can be made by referring to figure 1.

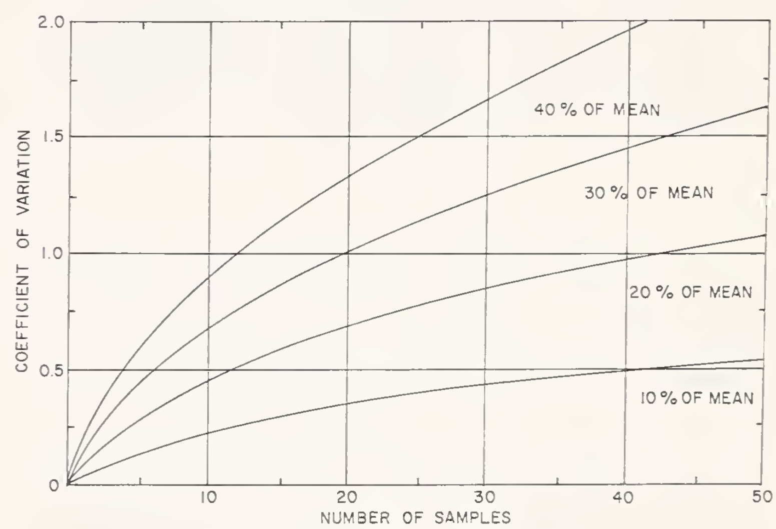

Figure 1.--Relation between sample variability and the number of samples needed for various levels of precision.

This figure is based on a 20 percent confidence level and has curves for ±10 to ±40 percent of the true mean for any coefficient of variation specified. The number of samples needed to reach an acceptable level of precision can be read directly from the curve without having to go through several approximations with the equation. Although a 20 percent confidence level is used

and is assumed to be acceptable for range sampling, curves for other confidence levels can also be easily prepared.

Data Extrapolation

Because funding and time constraints limit the amount of sampling that can be done, the system being described provides a basis for extrapolating present information to units of land where no information has been obtained. The data previously described can be used to extrapolate production estimates to land units where no sampling has been done. The range type or habitat type must be identified for the unit of land in question together with the land systems unit that has been mapped. The production estimates can then be used directly. It is best to keep the extrapolation of data within the mapped zones because of differences encountered between zones.

Restoration and Improvement Work

Land systems inventory and habitat typing have significant values in restoration work. Some important considerations include: (1) The land areas suitable for seeding, planting, burning, spraying, or for some type of mechanical treatment can be easily identified and a backlog of work needs programed for accomplishment, (2) predicted responses for any given environment can be made including planting success on trees and shrubs, increases in production following seeding or burning, limitations associated with hot or cold temperatures, moisture deficits or excesses, and slope stability and erosion concerns, and (3) seed collection and planting can be tied directly to the habitats of concern as well as selecting adapted species that will increase success of restoration projects. The need for such improvements as water developments can also be related to land units in a general way.

Erosion and Sedimentation

Slope instability and sedimentation are a major concern to land managers in the Idaho Batholith because sediment constraints are tied directly to management activities. In order to meet requirements in various plans, sedimentation associated with fire, road construction and maintenance, mining, grazing, and timber harvest activities must be planned for, controlled, and monitored closely. The land manager must understand slope stability as it relates to bedrock structure, texture, weathering, fracturing qualities, and landscape characteristics.

The sediment prediction procedure currently being used on the Boise National Forest is applied on watersheds that are stratified into land systems inventory units (USDA Forest Service 1981a). The model is used to predict natural sediment levels together with current rates and any increase that might be created by management activities. Cumulative effects are evaluated over time, taking any increase in sedimentation into account and evaluating the rate of return to natural levels. The information is useful in comparing impacts of different alternatives being considered in the planning process.

Because onsite erosion, as well as stream sedimentation, are evaluated, it is possible to predict average changes in water quality and to relate to fisheries interpretations. Although surface erosion is usually insignificant on forested watershed, it becomes an important factor to consider on lands disturbed by man's activities.

Mass erosion hazards related to soil failure and movement of material by gravity, either slowly or quickly, can be a significant factor on many landtypes. Therefore, hazard ratings are assigned to all landtypes and are used in the total sediment yield predictions on selected watersheds. By combining the sediment yields from natural processes with yields from surface erosion and mass erosion, a total sediment yield can be predicted. The ability of soil scientists and hydrologists to adequately predict sedimentation may truely determine the use constraints on critical watersheds in the near future.

CONCLUSIONS

Land systems inventory units combined with habitat typing concepts provide a useful land management framework. Resources available for management can be cataloged in an orderly manner using a land stratification system. Communications between disciplines are improved when land units have been clearly defined. This becomes a critical factor in more aspects than is commonly recognized. Sampling and extrapolation of data from one unit of land to another can be greatly improved. This can effect significant savings, which is important during periods with rapidly declining budgets. Predictive capabilities on sediment yields, site productivity, and response to restoration work are greatly improved by characterizing land units.

Because of these advantages, land systems inventories in combination with habitat typing concepts can be highly recommended for characterizing lands where management is being intensified. Continual improvement is needed to meet changes in management direction. This change is what makes management difficult, but it also provides challenges.

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PRINCIPLES OF WEED CONTROL AND PLANT MANIPULATION

James A. Young

ABSTRACT: Weed control and revegetation of degraded range sites is one of the most challenging tasks facing land managers. The manager must be able to assess the inherent potential for specific environmental situations to support and maintain plant growth. The land manager must also be able to assess the relative successional status of these environmental units. Any weed control treatment will initiate a dynamic successional plant response. The consequences of this response must be understood and directed toward desirable management goals or the weed control treatment will often lead to the establishment of a plant community less desirable than the treated one.

INTRODUCTION

The manipulation of species composition and density of plant communities through the application of weed control technology is one of the most challenging jobs facing land managers. Weed control on rangelands may be accomplished through the use of mechanical, herbicidal, grazing, or other biological techniques as well as by prescribed burning. Often weed control is accomplished through the application of two or more of these treatments applied on the same site.

Selecting Sites for Treatment

Matching the weed control methodology with the site is a formidable task in range improvement. An old and often used rule-of-thumb has been to improve the sites that have the greatest potential for production. This truism has to be tempered with some common sense. In a typical sagebrush-dominated rangeland the sites with the greatest potential productivity may be stringer meadows along streams. Obviously many meadows can stand improvement, but in terms of the forage base of the entire range unit, the upland sites have an aggregate production far in excess of the meadows, even though they have lower potential for forage production per unit of area.

The land manager has to know the potential for the individual range sites that compose a given unit of range and use range improvement techniques to fit the potentials. A classic practical example of this problem occurs when a land manager is faced with a proposal for brush control and seeding on a unit of a range allotment which consists of a mosaic of big sagebrush (Artemisia tridentata) and low sagebrush (A. arbuscula). The manager has determined that the area to be treated does not support sufficient perennial grasses to meet the site potential if the excessive amounts of brush are reduced. Because annual cheatgrass (Bromus tectorum) does not occur in the understory, the manager decides to spray with a 2,4-D and drill wheatgrass seed in the standing, dead brush. Because of the contrasting site potentials, the land manager has to decide whether the treatments are to be uniformly applied without regard to site potential or to be restricted on the basis of site.

Factors influencing this decision are the seedbed characteristics including rock cover and ease of drilling and the potential of the soil to support perennial herbaceous species. Besides these basic physical and biological characteristics, the land manager may base his decision on the contribution of the two sites to wildlife habitat or cultural resources. When the distribution of site potentials become very disproportionate, the land manager has the additional problem of physically applying the treatments. For instance, it may be more practical to apply herbicide than not to apply it to narrow stringers of low sagebrush that cut across the most desirable flight path to the big sagebrush sites that must be treated.

Current Species Composition in Relation to the Potential of the Site

In assessing site potential the range manager is estimating the ultimate productivity of the site after the vegetation manipulations are completed. The immediate problem is to assess the current vegetation in relation to the potential of the site.

Using our hypothetical example of a big and low sagebrush mosaic, let us suppose the low sagebrush sites have excessive brush cover, but also support a remnant stand of perennial grasses. These perennial grasses, because of more favorable conditions for grazing (slope, distance from water, etc.) are absent on the big sagebrush sites. Now the land manager may decide to treat the entire site with a herbicide for brush control while seeding only the big sagebrush sites.

James A. Young is a Range Scientist at the Renewable Resource Center, U.S. Department of Agriculture, Agricultural Research Service, Reno, Nev.

Within the big sagebrush communities, a variety of successional communities can be found occupying sites of the same potential. These range from pristine mixtures of shrubs, herbs and grasses to cheatgrass dominance in nearly monospecific communities. In between can be found brush-dominated communities with virtually no herbaceous understory species and shrub dominance with an understory of cheatgrass. The land manager must tailor his weed control and revegetation prescription to fit the successional stage.

Preemption of Site Potential

Probably the most basic truism in weed control is that ecologic voids do not persist. More simply stated--do not kill a weed and fail to replace it with something more desirable. If you proceed to create holes in plant communities with a weed control treatment without replacing the controlled species, the site will probably be occupied with an even less desirable species. This principle was the primary reason the herbicidal control of halogeton (Halogeton glomeratus) has stopped. Numerous herbicides control this poisonous weed, but land managers lack a desirable forage species to replace halogeton, especially on saline/alkaline soils.

Dynamics in Plant Community Structure

The control of big sagebrush with the herbicide 2,4-D provides many examples of the nature of plant community dynamics. A stand of big sagebrush is very stable where the majority of the plants are mature. Most seasons the plants probably do not even flower. If the shrubs are all killed with the application of 2,4-D, a series of dynamics is set in motion in the herbaceous vegetation. However, if the shrubs are only partially killed, the remaining shrubs will also respond dynamically. The shrubs that are not killed by the herbicide take advantage of the environmental potential released by the reduction in their density and flower profusely. Seeds from the flowers are dispersed to the seedbed under the shrubs where the big sagebrush seedlings can compete successfully. By the end of three growing seasons after herbicide application, the density of big sagebrush seedlings combined with the surviving plants may very well become greater than the shrub density before the herbicide was applied. The more shrubs controlled, within limits, the greater this dynamic reaction will be. Limits are established by killing sufficient shrubs to release enough environmental potential to fuel the dynamics and yet leave sufficient shrubs to support the seed production to initiate the dynamics. Unfortunately, for land managers, the shrubs can compensate for their reduced density with increased seed production per plant almost to their extinction. What this means, in terms of practical weed control, is that partial weed control is biologically very difficult to sustain.

This type of dynamics can be dampened by other biological fractions in the community. In the case of our big sagebrush example, the presence of sufficient established perennial forbs and grasses in the understory will offer severe competition to the brush seedlings and limit, but not eliminate, the dynamic establishment of the brush seedlings. This type of dynamics is not limited to the response of big sagebrush plants to applications of 2,4-D. The same response is commonly demonstrated when sagebrush communities that contain root- or crown-sprouting shrubs such as horsebrush (Tetradymia canescens) or green rabbitbrush (Chrysothamnus viscidiflorus) are burned in wildfires or prescribed burns. The dominant sagebrush does not sprout, but the subdominant shrubs sprout and for a transitory period dominate the site, not by the sprouts themselves, but by going through a dynamic seedling establishment phase. There is no more clear example of seed production dynamics than the one provided by cheatgrass after a wildfire. Because of consumption of cheatgrass seeds by the fire, the density of plants the next season is often reduced by 99 percent compared with adjacent unburned stands. However, seed production per unit of area may increase on the burn by the factor of 100. A stand of cheatgrass with only one plant per unit of area will produce 100 times as many seeds as 100 plants in the same unit of area would before the fire. Again the cheatgrass plants can compensate with increased seed production from more tillers and additional florets per tiller almost irrespective of the population density. In practical weed control, this is why a fallow treatment for cheatgrass control has to be as nearly completely free of this weedy pest as possible.

Selective Weed Control

Because ecological voids do not persist and partially controlled plant populations respond dynamically and return to or exceed original populations densities, it becomes highly desirable to select and control weedy plants and leave desirable species to suppress expressions of population dynamics.

This is the major reason for using herbicides rather than mechanical methods of weed control on rangelands. Mechanical weed control methods such as the use of chains are often selective, but the selection is seldom desirable in terms of management goals.

An example of herbicide selectivity is the use of 2,4-D to control shrubs while leaving grass species. The classic example of true physiological selectivity of herbicides involves the application of the herbicide atrazine (2-chloro-4-[ethylamino]-6-[isopropylamino]-s-triazine) for the control of weeds in fields of corn (Zea mays). The corn plants can metabolize the atrazine to a chemical that is harmless to their growth whereas few weed populations have

expressed an inherent capability for metabolizing this herbicide. Some populations of some species of weeds may contain the genetic potential to metabolize atrazine, but sufficient selection has rarely occurred to make the resistant forms dominant in the species.

Unfortunately, we rarely have the opportunity to utilize herbicides that are truly physiologically selective on rangelands. Selectivity is usually based on broad differences in growth form, such as grass versus broadleaf or differences in phenology.

Phenological selectivity is clearly demonstrated in the application of 2,4-D to remove big sagebrush plants from stands of bitterbrush (Purshia tridentata). Big sagebrush plants initiate growth and are susceptible to application of 2,4-D earlier in the spring than bitterbrush plants. When timing of herbicide application is carefully keyed to the phenological display of the two species and associated vegetation, selectivity can be obtained.

Phenological selectivity is a two-edged sword in herbicidal weed control. Often land managers must pay careful attention to plant phenology and associated environmental parameters to avoid selectively removing one weed species while leaving and thus favoring another weed species. The classic example of this phenomenon is the failure to control rabbitbrush in big sagebrush stands by incorrectly timing the application of 2,4-D. Application of herbicide should be timed primarily to control rabbitbrush. The more susceptible sagebrush will also be killed.

These physical and chemical characteristics of herbicides can be used to obtain a form of selective weed control. For example, the perennial wheatgrasses are susceptible to the herbicide atrazine. However, atrazine has a very low solubility in water. The relatively shallow rooted seedlings of cheatgrass can be selectively controlled in established stands of perennial wheatgrass because atrazine is not leached deeply in the soil before it is biodegraded so the deeper roots of the perennial grasses cannot absorb it. This is a relative type of selectivity greatly influenced by factors both within the perennial grasses and by post herbicide application environment. If the perennial grasses have been unduly suppressed by competition from the annual species and excessive pressure, their roots may be located at very shallow depths in the soil and the plants may have limited carbohydrate reserves. Both of these factors decrease the selectivity of the atrazine application. In addition, exceptionally heavy and prolonged precipitation may result in abnormal leaching of the herbicide destroying the selectivity.

A fallow treatment, such as the use of atrazine, to control cheatgrass in order to establish wheatgrass seedlings may seem to be a broad scale and, therefore, nonselective form of weed control. In actuality, the fallow process changes the physical nature of the seedbed and limits germination of cheatgrass seeds. It changes the characteristics of the seedbed through reduction of the litter accumulation on the soil surface. The loss of litter limits germination of seed on the soil surface where most cheatgrass seeds are located. This physical control, however, does not inhibit the germination of seed of broadleaf species such as tumble mustard (Sisymbrium altissimum) and Russian thistle (Salsola iberica). During the seedling year of the wheatgrass plants which follows the fallow period, tumble mustard and Russian thistle plants may compete with the wheatgrass seedlings. This competition can then be controlled selectively because the weed control involves the removal of a broadleaf from a seedling stand of grass. The original problem was to remove annual grass competition from a seedling stand of perennial grass, a situation where selectivity is virtually impossible. In this instance, manipulations of plant successions make selective weed control possible.

Foliar and Soil Active Herbicides

Many of our commonly used herbicides that control big sagebrush, such as 2,4-D, are applied as broadcast sprays. The droplets of herbicide in solution fall on the leaves of the shrub and are absorbed to be translocated in the plant. This type of herbicide is termed a foliar active material.

Other herbicides, such as atrazine, do not have a great deal of foliar activity, but are readily absorbed by roots. Such herbicides are termed soil active. Many herbicides have both foliar and soil activity. Picloram (4-amino-3,5,6-trichloro-picolinic acid) is a good example of this type of herbicide. The relative amount of soil and foliar activity is dependent on the target species and the rate and formulation of the herbicide being used. Picloram is applied as a potassium salt in a solution with water to control green rabbitbrush. In this case, it is a foliar active herbicide. When picloram is applied to the base of the juniper trees as a 10 percent a.i. granule, it is a soil active herbicide.

In the past, herbicides that are largely soil active have been misnamed soil sterilants because some of them have been used to denude areas of vegetation for extended periods, mainly in industrial weed control programs. Soil active herbicides can be used as soil sterilants, but this use is entirely related to the rate at which the herbicide is applied. Soil active herbicides used to bare soil in industrial weed control usually have a very broad spectrum of weed control activity against a number of plant species.

The application of foliar-applied herbicides is often related to the phenology of the target species. You only apply the foliar active materials when conditions are correct for absorption and translocation. In the sagebrush-grass environment, foliar active herbicides are applied during the active growth period in late spring. The activity of soil-applied herbicides is tied to their movement into the soil and the rooting zone of the target species. On rangelands we rarely mechanically incorporate herbicides into the soil. Incorporation is dependent on moisture events to move the herbicide into the rooting zone. Therefore, the timing of application of soil-active herbicides is in relation to the occurrence of moisture events. In the sagebrush-grass environment, soil-active herbicides are applied in the fall.

Soil active herbicides applied for the control of herbaceous annuals such as cheatgrass are not effective on dormant seeds. The plant must germinate, exhaust food storage in the seed, and absorb the herbicide through the roots before the soil-active material is effective.

Suppression Versus Eradication

When herbicides first became available for use on rangelands, the term eradication was often used in reference to control of such species as big sagebrush. Experience has shown that eradication is neither biologically possible nor desirable. Range weed control treatments are designed to give a temporary shift in plant succession. This successional shift is given a time duration by revegetation and grazing management. You can control big sagebrush with 2,4-D, but the treatment has a limited half-life unless the perennial herbaceous vegetation is encouraged and maintained through grazing management. You can control cheatgrass with atrazine, but the shift in successional status is extremely brief unless the site is revegetated with desirable herbaceous perennials.

Once the desirable perennial dominated herbaceous species gain a position of dominance in a rangeland community, they will suppress the expression of seedlings of perennial shrubs or annual grasses, but they will not eliminate these life forms from the community.

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PLANTING LIMITATIONS FOR ARID, SEMIARID,

AND SALT-DESERT SHRUBLANDS

Gilbert L. Jordan

ABSTRACT: A major limitation in revegetation of semiarid rangelands is the ability to identify temperature and precipitation values which limit successful range seedings. This identification process is difficult because of non-uniform descriptors of arid lands and climates or absence of suitable data. However, empirical values which identify arid zones, or inadequate precipitation for successful seedings, can be obtained through Köppen's classification of dry climates based on annual temperatures and seasonal distribution of rainfall. The use of this classification in developing guides for seeding semiarid zones is illustrated. The relation of these guides to soil texture, germination rates, drought tolerance, and seedling vigor is briefly discussed.

INTRODUCTION

Revegetation of dry range sites is a difficult task on western rangelands. Almost immediately one is faced with the decision of whether the site is too arid or of borderline acceptance. However, the distinguishing factors between the two conditions are not clearly defined. The primary objective in the following discussion is to develop guidelines to characterize arid, semiarid and salt-desert shrub sites in relation to their potential for successful range seedings.

The first guide provides a basis for rejecting sites that are too arid, followed by guides limiting seeding on sites that otherwise appear favorable. The first fundamental element in developing these guides is moisture--how much and when is it needed? The second element is temperature which affects precipitation efficiency and plant growth rates. The third element is the correlation of moisture and temperature with the requirements for germination, the most critical phase in seedling establishment in dry climates.

CORRELATION OF CLIMATIC AND BIOTIC FACTORS

In defining climatic limitations for seeding of various range sites, terms or classifications should integrate the physical processes of precipitation, evaporation, temperature and other factors with plant responses; recognizing that changes in rate of physical processes do not always elicit parallel or linear rates of change in affected biological processes. To illustrate: it might be reasoned that the vapor pressure of water at various temperatures can be used to predict the potential evaporation and consequent water requirements of plants (fig. 1). Within the range of temperatures for plant growth from approximately 40° to 80°F (4 to 27°C) there is over a four-fold increase in vapor pressure, indicating a four-fold increase in evaporative potential or water requirement. These temperatures could be representative of a cool-season seeding and a warm-season seeding, respectively. While it might appear that the warm-season site would require four times more precipitation to be as effective as the cool-season site, this is not the case. My experience indicates that precipitation requirements would be about double the cool-season requirements. The rate of evaporation is much higher in the warm-season site, but species adapted to the warm-season site will usually germinate at higher rates and have higher growth rates. The cause and effect and direction of change is obvious but the magnitude is variable, depending on the species of plant.

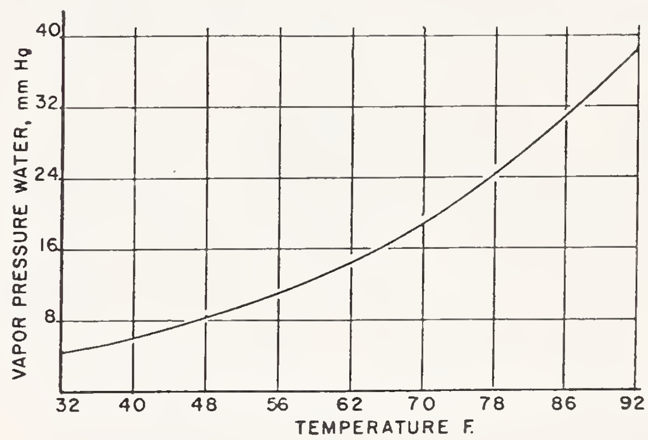

Figure 1.--The relation of equilibrium vapor pressure of water over a selected temperature range (Weast and Selby, 1967).

Data from physical and biological processes, arising from observation and experiments, are often used to conceptually integrate physical and biotic factors. Moisture availability for germination in arid to semiarid regions is typically of short duration. In fact, the difference between a range seeding success or failure under hot desert temperatures may depend on a critical period of less than 24 hours of available soil moisture for that particular year. A typical relationship between field moisture conditions and germination response in a range seeding is illustrated in fig. 2. This illustrates that the rate of germination is of much greater importance than the total germination percentage in determining which

Gilbert L. Jordan is a Range Management Professor at the School of Renewable Natural Resources, University of Arizona, Tucson, Ariz.

species may be functional within a selected probability of having sufficient moisture. Fortunately, germination rates, the time to 50 percent germination, can be determined with a high degree of precision for most ecotypes. The probability of receiving moisture cannot be determined as readily because the variability of precipitation is probably the most consistent feature of dry range regions.

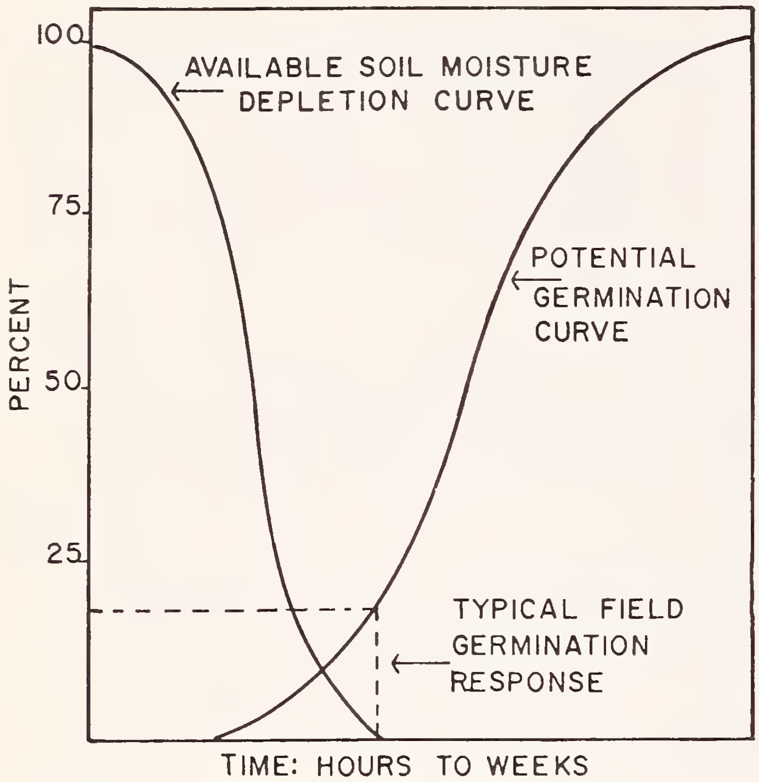

Figure 2.--Only the most rapidly germinating seeds contribute to successful range seedings under typical limited moisture patterns of rangelands.

Any climatic limitations proposed as guides in range seeding should be applied on a limited scale due to wide physical and biological variations. For our purposes, this limited scale refers to semiarid sites of the western United States using typical forage species. The limitations discussed hereafter are not meant to explain the general plant ecology of the region. As indicated by Evanari, and others (1971), the more extreme the plant's habitat, the more specific the plant's adaptation, the greater the variety of adaptive mechanisms, and the greater the variation in responses to the environment.

There is also a wide latitude in the meaning of terms used to describe various range sites or types. The terms arid, semiarid, desert, steppe, semi-desert, salt-desert shrubs, or dry versus humid climates have been used by climatologists, ecologists, geographers, range managers and others with no degree of uniformity (McGinnies 1968). The borderline between dry and humid climates has been defined as that point where precipitation is just adequate to meet the demands of evapotranspiration--truly a lush range site. Some define deserts as areas receiving 10 inches (25 cm) or less of annual precipitation. The Antarctic thus qualifies as a desert. An extreme desert has been defined as one in which no measurable precipitation has been recorded in a 12-month period. Thus, terms such as "dry climates" or "deserts" or "arid" are not sufficiently descriptive to guide us in seeding of western rangelands. There are over two dozen different indexes of aridity presented in the literature; none are universally applicable as range site descriptors. Most are too general for specific range sites or require data or sophisticated instruments which are not available (Reitan and Green 1968).

To clarify the terms arid and semiarid in regard to range seeding, the classification of arid/semiarid sites needs clarification with respect to temperature. The four American deserts--Chihuahuan, Sonoran, Mohave, and Great Basin--are classified as hot and cold deserts and each has arid and semiarid regions with characteristic precipitation patterns. Hot deserts are those having an average annual temperature of 65°F (18°C) or above (Trewartha 1957). Warm deserts would be under 65°F. Cool deserts have at least one month averaging below freezing, generally indicated by average annual temperatures below 52°F (11°C) Espenshade and Morrison 1974). These values provide approximations for selecting between warm and cool-season species. They are approximations even though limiting values have been given. In reality, it is similar to defining the precise boundary between night and day.

Range seeding studies in Arizona indicate areas having an average annual temperature above 65°F should not be recommended for seeding because they are too arid (Jordan 1981). The relationship is partly due to the fact that high temperatures tend to be correlated with low precipitation. Warm-season species are recommended for warm deserts because they do not germinate well in cool-season seedings. Generally, average annual temperatures should be 55°F (13°C) or more before warm-season species can be considered for possible spring or summer seedings if precipitation is adequate. Conversely, cool-season species will not endure high summer temperatures. The seeding of cool-season species is recommended for those areas having average annual temperatures below 55°F where the season of seeding is in the fall. When seedings were attempted on semiarid sites having average annual temperatures approaching 45°F (7°C), low temperatures often were limiting even though moisture was present. I have recommended that hot deserts are above 65°F, warm between 55°F and 65°F, cool between 45°F and 55°F, and cold below 45°F (Jordan 1981).

RANGE SEEDING POTENTIAL AND KÖPPEN'S CLIMATIC MODEL

A classification that appears valuable for range reseeding in the western U.S. is the one based on Köppen's classification of dry climates, apparently developed from empirical relationships for general climatic zones based on average annual temperature (AAT) and seasonal rainfall distribution. Although it has been used for general climatic mapping, it is not known to have been applied to specific range sites. This classification is presented as a working model to set the lower arid limit for the seeding of western rangelands. This model, depicted in fig. 3, was derived from Trewartha's selected empirical relationships between temperature and precipitation (Trewartha 1957). For example, the boundary between humid and semiarid zones, where the rain-

fall is not strongly seasonal, is determined from equation R = 0.44T - 8.6 where R is inches of annual rainfall, T is annual temperature in degrees F, and 8.6 is a factor used to adjust for seasonality of precipitation. The boundary between arid and semiarid is one-half the humid/semiarid boundary. Thus, the boundary between humid and semiarid at 60°F (16°C) is 18 inches (46 cm), and between semiarid and arid it is 9 cm). inches (23 cm). This boundary will shift depending on whether precipitation occurs mainly in summer or winter, and the following seasonality factors may be used to adjust this boundary: (Adapted from Trewartha 1977)

Percent summer percipitation	Seasonality factor
0	3.1
10	4.2
20	5.3
30	6.4
40	7.5
50	8.6
60	9.7
70	10.8
80	11.9
90	13.0
100	14.1

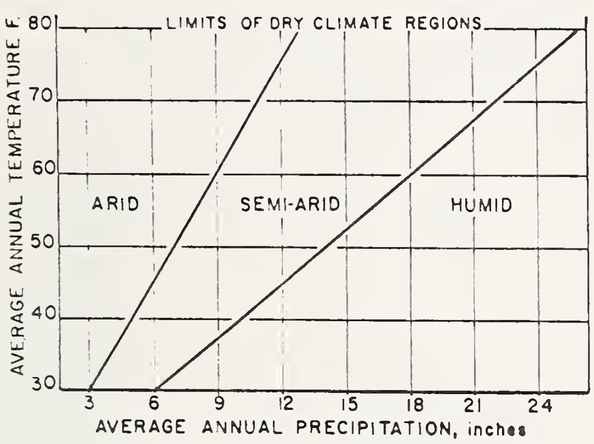

Figure 3.--A division of dry climates based on average annual temperatures and precipitation. Divisions shown are applicable only where amounts of winter and summer precipitation are similar.

In dry regions of the world other than western U.S., other factors or climatic classifications might be necessary to account for the relative importance of summer or winter precipitation in relation to the effective period of growth. For general comparative purposes, it is suggested that months having average temperatures above the annual mean be considered summer months for calculation of summer precipitation. The obverse would be used for winter precipitation. The range between the extremes of precipitation or temperature may be considered in conjunction with seasonal distributions (Lustig 1968). For western rangelands, the arid zone boundary derived from the model can be related to the relative success of range seedings.

APPLICATION OF MODEL TO WESTERN RANGE SITES

Arizona seeding studies indicated limitations with respect to using average annual precipitation. While average annual precipitation values are often used to characterize range sites, they were not adequate to describe the reseeding potential of a site. It was not until seasonality of precipitation, the arid/semiarid boundary, and the average annual temperature were considered that predictive values of potential could be estimated. This can be illustrated from reseeding studies conducted at Wickenburg and Bowie, Arizona. Wickenburg has an AAT of 65°F (18°C) and average annual precipitation (AAP) of 10.7 inches (27.2 cm), of which 4.3 inches (10.9 cm) are received during the growing period of July, August, and September. AAT restricts seedings to warm-season species. With the seasonality factor (see above) of 7.5 (40 percent summer precipitation), the arid/semiarid boundary is 10.5 inches (26.7 cm). Bowie has an AAT of 64°F (18°C) and an AAP of 9.9 inches (26.7 cm), of which 55 percent or 5.4 inches (13.7 cm) is received during the same growing period. The arid/semiarid boundary, based on a seasonality factor of 9.2, for Bowie is 9.5. Both the Wickenburg and Bowie sites have precipitation values for their arid/semiarid boundaries almost equal to their AAP (fig. 4). Both sites have similar loam soils. Successful seedings cannot be made at Wickenburg. On sand-dune mesquite sites at Bowie, seedings can be successfully established from 50 to 75 percent of the time even though Bowie has a lower AAP.

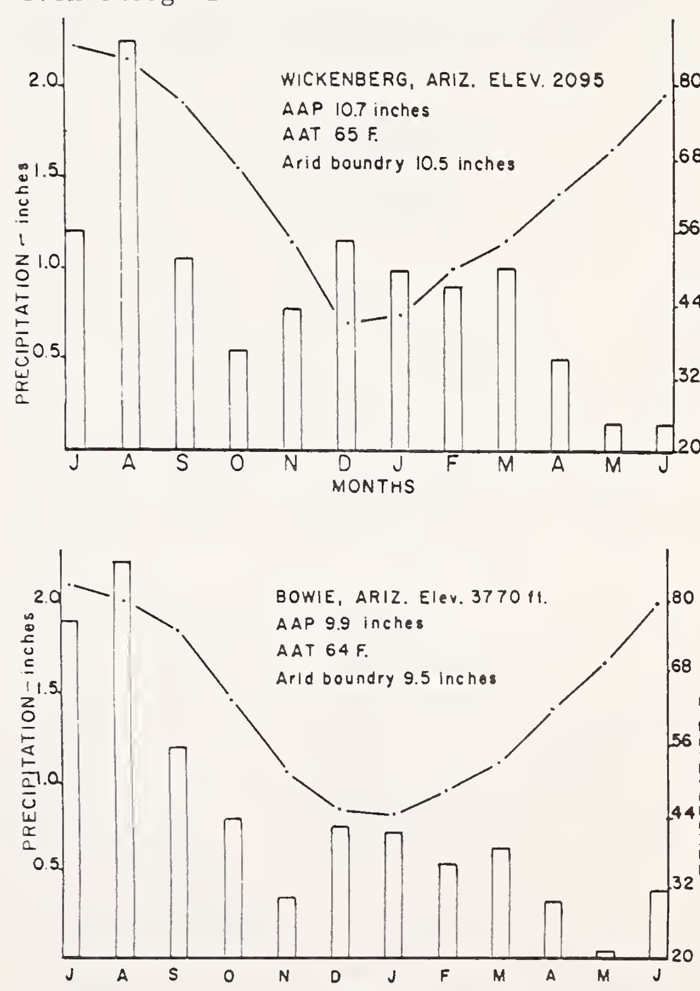

Figure 4.-- Monthly values for precipitation and temperature for two warm-to-hot desert areas in Arizona.

The arid/semiarid zone boundary was thus indicated as a value for rejecting arid sites for seeding. Furthermore, as a guide for semiarid sites in warm deserts, there must be a minimum of 5 to 6 inches (12.7 to 15.2 cm) of summer precipitation before seedings are contemplated. Evaluations of numerous seeding studies in Arizona were used in developing this guide. In all instances, sites which were classified as arid were not suitable.

With respect to the cool Great Basin Desert, winter temperatures also must be considered in conjunction with precipitation efficiency (fig. 5). For example, Fredonia, Arizona has a 9.4-inch (23.9 cm) AAP and an AAT of 52°F (11°C) giving an arid/semiarid zone boundary of 7.4 inches (18.8 cm Cool-season species are indicated. Summer precipitation is 2.5 inches (6.4 cm) during July, August, and September and winter precipitation is 3.6 inches (9.1 cm) during November, December, January, and February. From 3 to 4 inches (7.6 to 10.2 cm) of effective moisture was generally necessary through the winter season to promote adequate germination and seedling growth from fall seedings at Fredonia. Research at Fredonia indicated when average monthly temperatures fall below 32°F (0°C) that germination has ceased or is extremely slow. Soil moisture can be lost through evaporation while germination is curtailed. Deep soil moisture remains effective for root growth under favorable temperatures. Late spring or summer seedings in the Fredonia area are not successful unless they are followed by 4 to 5 inches (10.2 to 12.7 cm) of precipitation. Fredonia is semiarid and marginally suited for seeding due to the amount and seasonal distribution of precipitation.

Other examples can be used to illustrate the use of average annual temperature and precipitation values to guide range seedings. Vale, Oregon is the general site of extensive fall seedings. It has an AAP of 9.4 inches (23.9 cm) and an AAT of 51°F (10.6°C). The arid/semiarid boundary is 7.1 inches (18.0 cm), which indicates Vale is semiarid, having the potential for seeding of cool-season species. Evaluation of the monthly precipitation shows a major winter precipitation distribution of 4.25 inches (10.8 cm), during which January averages below freezing. Subtracting the 1.25 inches (3.2 cm) of precipitation for January leaves 3 inches (7.6 cm) for germination and seeding establishment. This conforms to the limits of 3 to 4 inches (7.6 to 10.2 cm) required for fall seedings. Another peak precipitation period during May is particularly favorable for subsequent growth but not adequate to support a late spring seeding.

Elko, Nevada has an AAP of 9.7 inches (24.6 cm) and an AAT of 45°F (7.2°C). Calculations from this temperature would place the arid/semiarid boundary at 5.8 inches (14.7 cm), and thus Elko should be suitable for seeding. However inspection of seasonal distribution of precipitation and temperature indicates at least 3 months average below freezing until March 1st, which precludes the use of 3.0 inches (7.6 cm) of winter precipitation as effective precipitation for germination. Fall seedings would be indicated with germination and seedling establishment occurring from March through June. During this time the temperature averages 47°F (8°C) and effective precipitation would be about 3.5 inches (8.9 cm), which falls above our predicted limits for seeding cool-season

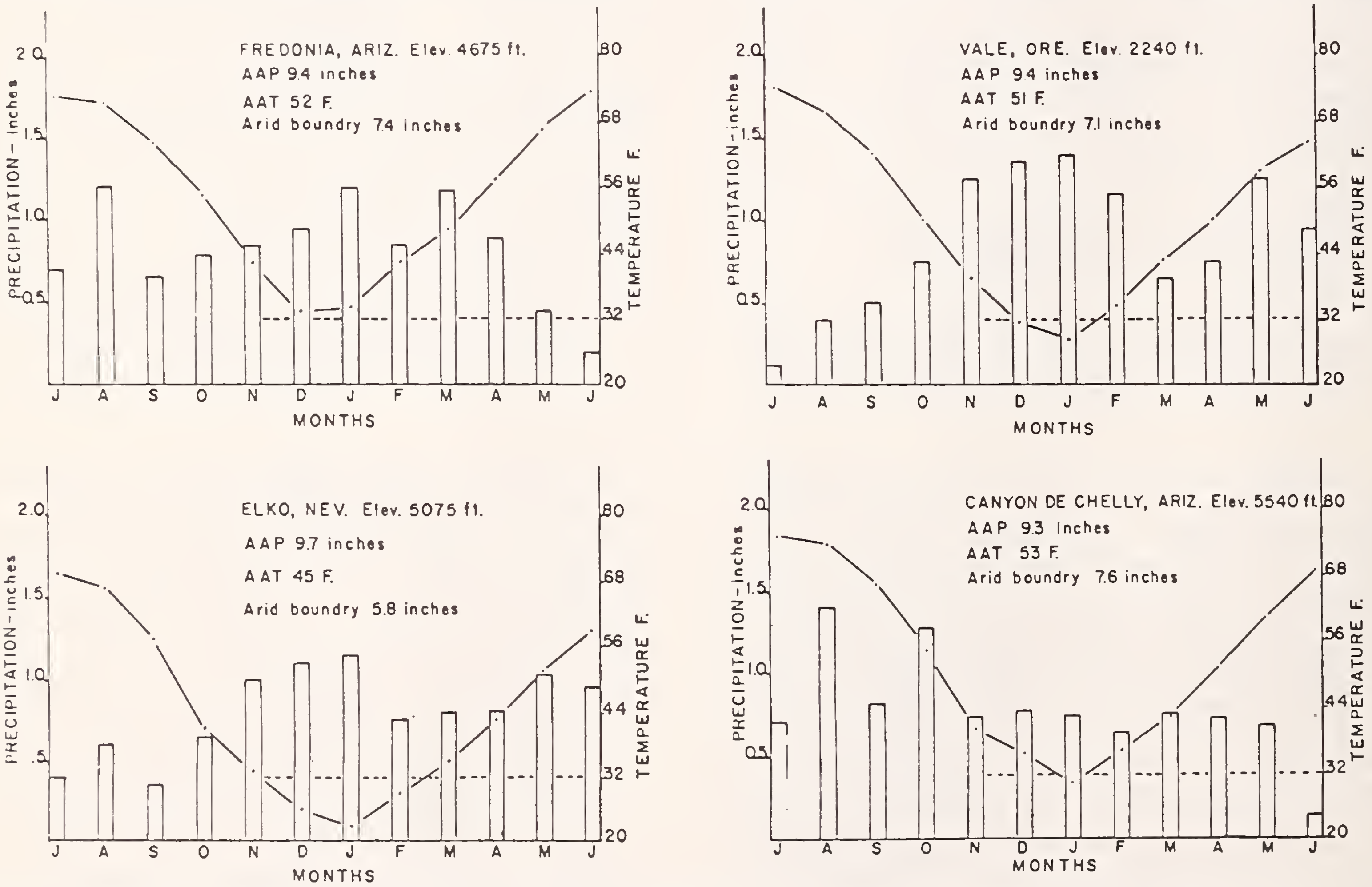

Figure 5.--Monthly values for precipitation and temperature for selected sites in cool-desert areas. The boundary for freezing is shown for reference.

species. The low AAT, however, indicates this area might be borderline because low temperatures would be responsible for seeding failures in some years.

Finally, Canyon de Chelly, Arizona can be used to illustrate some additional limitations to seeding. Canyon de Chelly has an AAP of 9.3 inches (23.6 cm), an AAT of 53°F (12°C) and a calculated arid/semi-arid boundary of 7.6 inches (19.3 cm). The AAT indicates cool-season species should be planted, but the winter precipitation of 2.26 inches (5.7 cm) is below the required 3 to 4 inches (7.6 to 10.2 cm). Also, the 3.8 inches (9.7 cm of summer precipitation is below the required 4 to 5 inches (10.2 to 12.7 cm). While the arid/semiarid boundary value of 7.6 inches (19.3 cm) is below the AAP of 9.3 (23.6 cm), this site is too arid to seed. Inspection of monthly temperature and precipitation shows an almost uniform distribution of precipitation throughout the year. Thus, for seeding success it is better for precipitation to occur seasonally rather than be distributed uniformly. There is much greater loss by evaporation from small, uniformly distributed storms rather than from larger storms. For germination in the warm desert areas, singular summer storms delivering less than 0.6 to 0.7 inches (1.5 to 1.8 cm) precipitation are of little or no value. It is only after roots are developed that moisture from smaller storms can be utilized. In contrast, storms delivering from 0.3 to 0.5 inches (0.8 to 1.3 cm) of precipitation during the winter are effective during the germination period of fall-seeded, cool-season species. In recapitulation, no seedings should be made in arid zones as defined by Köppen. Seedings in semiarid zones can be made if limitations of amount and distribution of precipitation and temperature are observed.

RELATION OF MODEL TO EDAPHIC FACTORS

Soil conditions also need to be considered with respect to precipitation effectiveness. Only an over-simplified discussion will be given at this time. Starting with sandy soils, there is rapid water penetration, but a low water holding capacity of about 13 percent. Next are the loam soils in which water penetration is slower but still very good. Water holding capacity is good with field capacities up to about 30 percent. Total available water is highest in this soil type. The moderately fine and fine textured soils, such as silty clay loams and other clay soils, have lower infiltration rates, attain field capacity at about 35 percent, but they do not have more total available water than the medium textured loams. The most desirable soils for reseeding are generally the medium textured soils due to their good intake rates, good water holding capacity, and good aeration.

Medium-textured soils are implied when the limits for precipitation following seeding are given, i.e., 3 to 4 inches (7.6 to 10.2 cm) for fall seeding in the cool desert, 4 to 5 inches (10.2 to 12.7 cm) for spring-summer seedings in cool deserts, and 5 to 6 inches (12.7 to 15.2 cm) for spring-summer seedings in warm desert areas. If the soils are clay loam, silty clay loams or finer textured, precipitation should be 20 percent higher than the above limits to allow for (1) poorer infiltration rates and (2) probable greater total loss from evaporation. Similar allowances must be made for the salt-desert shrub types because of their often finer-textured soils. Because of their topographic position and/or source of parent material, these sites can be either or both saline or alkaline. Due to the physiological imbalance imposed on plant growth by these sites, drought effects are intensified. Salinity promotes physiological drought and the resulting dispersed soils physically increase drought through poor water penetration. These sites are named from the characteristic vegetation frequently associated with them. In general, these plants are members of the goosefoot family, consisting of such species as black greasewood, saltbushes, kochias, winterfat, and shadscale. The presence of these species frequently indicates saline or alkaline soils, or at least areas more arid than the sagebrush rangelands.

INDICATOR SPECIES AS SUPPLEMENTAL GUIDES

The characteristic association of certain species with certain soils and/or climatic conditions has given us the term indicator species. As has been illustrated, an exact combination of precipitation and temperature conditions cannot be specified for determining the limits for reseeding because we do not know all the limitations of the species we are trying to seed. However, through experience we have learned that the presence and vigor of certain species can be associated with the success or failure of a range seeding. Indicator species can complement the guides previously presented. For example, the association of sand-dune mesquite and soap-tree yucca in southeastern Arizona indicates a poor to fair site for seeding. In the same area, creosotebush indicates unsuitable sites. Velvet mesquite sites are generally suitable, but foothill palo verde sites are not. Big sagebrush sites having large thrifty plants are generally suitable, but blackbrush sites occurring at the southern limits of big sagebrush are not suitable. The presence of Joshua trees indicates influences of the Mohave Desert and an unfavorable site for reseeding. There are numerous other examples that could be cited for broad general areas and for small specific sites. It should be remembered that indicator species are approximate guides and will not be accurate in all cases. But, as initially indicated by Plummer and others (1968) and as illustrated by the foregoing discussion, the nature of the precipitation in conjunction with seasonal temperatures and the presence of an indicator species are important guides as to which species and sites might be successfully seeded.

RANGE SEEDING POTENTIAL AND BIOTIC FACTORS

In correlating plant responses with climatic and edaphic parameters, certain plant characteristics become paramount. In the selection of species for seeding arid, semiarid and salt-desert sites, it seems redundant to state, "Select only the most drought resistant species." However, this is the

first and most fundamental criteria to start with, but drought tolerance in one area does not always mean drought tolerance in another. Crested wheatgrass has been a persistant species on thousands of acres in the Great Basin Desert. When seeded under similar precipitation and temperature limits on the Arizona Strip, it does not persist. It is believed for crested wheatgrass that moisture and temperature conditions on the more arid sites of the Strip are unfavorable during flowering. Flowering readily occurs but seed is not set, presumably because of blasting of the pollen. Thus, the stand cannot regenerate itself and rodents eventually remove most of the original plants. Resistance to drought must be considered throughout the phenology of the plant.

Over the short term, a false sense of achievement can be attained when an excellent stand of grass is established on certain semiarid range sites. Lehmann lovegrass was established in the San Simon Valley in southeastern Arizona, creating a beautiful stand of grass for several years. Over a 12-year period, the stand declined to nothing on certain sites. It was suspected that a series of dry winters in conjunction with the shallow root system of Lehmann lovegrass diminished the stand. Hence, drought tolerance is not a simple criteria to measure; it cannot be extrapolated without caution from one area to another, and it might take years to verify.

A second criteria for selecting species for semiarid or salt-desert shrub sites is rate of germination. This criteria, alluded to earlier in this discussion, is emphasized here as being a factor over which we can exercise some control. Characteristically, there might not be more than 3 to 7 days out of the entire year when both temperature and moisture are favorable for germination. Under these conditions, only species having high rates of germination can be established, and it can be noted that almost all the common species used in revegetation have high germination rates. This is due to the limitations of time and money available and the constant requirement that seedings be moderately to highly successful. Not all indigenous species have high germination rates which may not necessarily be required or advantageous from an ecological standpoint.

A third criteria for selecting species for semiarid sites is the poorly-defined factor of seedling drought tolerance and seedling vigor. An excellent forage grass for seeding semiarid, cool desert sites is Russian wildrye, but its seedling vigor is relatively low. Thus, its use is restricted. In contrast, crested wheatgrass has high seedling vigor and seedling drought tolerance. Sideoats grama has a very high germination rate, but it is not easily established except in years of above-normal rainfall. Apparently the seedling is drought sensitive. After the seedling stage, Russian wildrye is highly drought tolerant, and sideoats grama is moderately drought tolerant. It is interesting to note that many of the shrubs, whether weedy or desirable, are not as cold or drought tolerant in the seedling stage as are the drought tolerant grasses.

Thus far I have refrained from recommending any particular plants for seeding semiarid, or salt-desert shrub sites. The emphasis has been on criteria for rejecting sites too arid to seed and for evaluating semiarid sites that are borderline. The reseeding of these sites might be governed by how much time and money is available to put out at a certain risk level. Having decided to take the risks, the species available are not unique but are those proven to be responsive for seeding on semiarid sites. There are essentially no plants for seeding on arid sites.

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Section 2. Manipulation of Plant Communities

FIRE AS A VEGETATION MANAGEMENT TOOL

IN RANGELANDS OF THE INTERMOUNTAIN REGION

Richard P. Young

ABSTRACT: Fire has been an important factor in the evolution and development of many range ecosystems. Today, prescribed burning is recognized as a tool useful for manipulating vegetation, often accomplishing several management objectives simultaneously. Successful use of prescribed burning is based on an understanding of the ecological effects of fire, fire-weather-fuels interactions, and proper management of areas treated with fire. These topics are discussed with respect to using fire as a management tool in the sagebrush and pinyon-juniper zones of the Intermountain region.

INTRODUCTION

The sagebrush and pinyon-juniper zones occupy several hundred thousand acres within the Intermountain region of the Western United States. These ecosystems hold vast potential for manipulation through the controlled use of fire. Historically, fire has played an important role in sagebrush and pinyon-juniper rangelands. These communities have evolved under the influence of periodic burning. Prior to westward emmigration by white man, fires were started by lightning and were purposefully and accidentally set by Indians. Fire burned sagebrush-grasslands at intervals of 32 to 70 years (Houston 1973) to as often as 7 to 17 years (Martin and Johnson 1979). Pinyon-juniper communities had fire frequencies of 10 to 30 years (Leopold 1924; Burkhardt and Tisdale 1976), probably restricting these trees to shallow, rocky soils and rough topography.

Much of the current appeal of prescribed burning derives from the view of fire as a natural component of range ecosystems. Additionally, interest has been stimulated by concern over the large scale application of herbicides and their effect on nontarget species, and the high costs of mechanical treatments in range improvement projects. As a result, the use of controlled burning has increased dramatically in recent years and is now recognized as a valuable means of managing vegetation of the sagebrush and pinyon-juniper zones.

Common and scientific names of plant species considered herein are listed at the end of this paper in the section entitled "Plant Species Names."

Richard P. Young is Graduate Research Assistant at the Eastern Oregon Agricultural Research Center, Burns, Oreg.

USES OF FIRE

Some current applications of prescribed burning in sagebrush and pinyon-juniper communities include:

1. Reduction of woody species competition. The primary use of prescribed burning in these communities is to reduce cover of the woody dominants--sagebrush, pinyon, and juniper. (Wright and others 1979; Blaisdell and others 1982). Multiple benefits are often obtained by this treatment. Increased production, nutrient quality, and palatability of herbaceous plants are observed after a burn. Fire increases production and availability of sprouting browse species. Additionally, fire breaks up large tracts of sagebrush and pinyon-juniper dominated landscapes. This results in greater habitat diversity by establishing a mosaic of vegetation types. Therefore, both domestic livestock and wildlife can benefit when prescribed fire is properly used.

2. Site preparation. Prescribed burning has been used in sagebrush-cheatgrass and cheatgrass-annual forb communities to prepare sites for subsequent seeding to improved species such as crested wheatgrass (Pechanec and Hull 1945; Young and Miller 1983). Fire is used to remove sagebrush and to reduce cheatgass density, and therefore, to reduce competition with emerging seedlings of the seeded species. In pinyon-juniper communities fire is used for site preparation after chaining or dozing and prior to seeding. Here, fire is employed primarily to reduce wood residues of uprooted trees and shrubs. A secondary benefit of broadcast burning (as opposed to burning piled or windrowed debris) is obtained by killing small trees and shrubs that survive the mechanical treatment. However, over much of the Intermountain region, sparse understory vegetation limits the application of broadcast burning in mechanically treated pinyon-juniper areas.

3. Repeat treatment of improved sites. A use of fire yet to be fully explored consists of burning sites where sagebrush and/or pinyon and juniper were previously controlled by mechanical methods. Reinvasion of undesirable woody plants reduces production of native grass-forb and seeded grass stands. This often creates a need for retreatment after 20 to 40 years. If herbaceous fuels are sufficiently abundant, fire may be used to renovate these stands.

FIRE EFFECTS ON VEGETATION

Some General Concepts

Two aspects of fire effects on vegetation need to be considered: (1) direct effects, which consist of heat damage to individual plants; and (2) indirect effects--that is, how fire affects postburn community development by altering stand composition and structure. Direct damage by fire is related to morphological characteristics of plants, including the location of growing points (meristematic tissues). Development of the postburn community as a whole is obviously dependent to a large degree on direct fire effects. There are, however, some additional factors at work. By killing certain plants, fire reduces competition and releases resources (water, nutrients, light) to those plants that survive the burn and to new plants established from seed within the burn area. How these newly available resources are divided is dependent on characteristics of the plant species, including their regrowth and reproductive potentials, and preburn range condition--species composition and abundance.

All trees and shrubs and some perennial forbs have growing points elevated on aerial stems, the terminal and lateral buds. These are often severely damaged or killed by fire. Survival of these species is dependent on their ability to resprout after loss of aerial stems. For example, certain shrubs resprout after burning as top-killing activates dormant buds or initiates development of adventitious buds at the lower portions of stems or on roots (Volland and Dell 1981). Most grasses and forbs have growing points variously insulated from heat injury by their location near to or below the soil surface. For these species the degree of damage sustained is proportional to the temperature and length of time to which meristematic tissues are subjected. Postburn regrowth is by way of undamaged meristematic tissue. Most herbaceous plants fall into this category, and response to fire varies between species and with characteristics of the burn. Rhizomatous species are usually quite resistant to fire injury due to insulation of growing points by the soil (Volland and Dell 1981).

Plants capable of rapid regrowth or resprouting after fire are usually favored over those that are top-killed and subject to reestablishment by seed (Noble and Slatyer 1977). These species are able to take immediate advantage of the increased availability of resources. This is often observed as vigorous growth and increased production of individual plants, species, or the herbaceous component of a community as a whole (Daubenmire 1968; Young and Evans 1978). This alone, however, does little to fill in the spaces resulting from plants killed in a fire. That is accomplished primarily by the establishment of new plants from seed (although spread of rhizomatous species achieves the same result). Seed availability and ultimately establishment of new plants can affect postburn community composition as much or more than any other process. Therefore, seed production, longevity, and dispersal characteristics are important with respect to community development after a fire (Harper 1977; Cattelino and others 1979). Species with the best chance of getting seed into "open" sites, favorable for successful establishment, are likely to have one or more of the following properties:

1. Production of large seed crops. The more seed produced, the greater the chance of some falling onto favorable sites.
2. Seeds that are light and/or have special morphological characteristics to aid dispersal. The adaptation of many weedy species and some shrubs, especially when combined with the property of large seed crops, results in highly competitive species because seed is broadcast over large areas and new plants may rapidly occupy suitable openings within a community.
3. Reserves of long-lived seed maintained in the soil. In this situation a ready supply of new seedlings may be available to occupy openings without the delay of seed production and dispersal into the burn area. A certain proportion of the seed reserves may germinate on an annual basis or germination may be stimulated by conditions of the burn such as heat treatment from the fire or high levels of nitrogen and/or phosphorous in soils after the burn.
4. Annual or frequent seed crops. Because good seed production years are not always followed by good seedling establishment years, it may be advantageous to produce some amount of viable seed in as many years as possible. Several years may be required before seedlings are capable of taking hold in a burned area.

Although not a property of seed production per se, the more abundant a species is within the postburn community, the more likely it is to spread into fire-created openings, either by vegetative growth or establishment of new seedlings; thus, the importance of preburn range condition and survival of desirable species. Poor condition or low seral stage communities probably will not improve in response to fire either rapidly, or possibly not at all (Young and others 1977; Young and Evans 1978). Where the perennial grass and forb understory is depleted, total seed production will be small and poorly dispersed over the burn area (even though production per plant may be relatively high). Resprouting shrubs and annual species are likely to increase and compete strongly with the more desirable plants. In general, the better the initial condition of the site, the more likely it is that a favorable response will be observed after a fire.

Plant Species Response To Fire

Despite the inferred difficulty of predicting plant response to fire, an abundance of information exists on certain species (especially the common, abundant ones) and how they react to fire. About some species, we know a lot, and our predictions concerning these are generally quite good. For others, however, we know much less. Caution is therefore advised when using summaries (such as I report here) for the following reasons:

1. Much of our information derives from observations following wildfires. Environmental conditions and behavior of wildfires are typically different from most controlled burns. Therefore, plant response might similarly be expected to differ significantly. We still need to know more about plant response to burns of varying intensities conducted in different seasons, phenological condition, soil moisture, and so forth.

2. Many times generalizations are formulated about species occurring in low abundance in a community. These species are difficult to sample with reasonable levels of precision. Although no hard and fast rule can be given, the key to evaluating fire effects on these species is to look for "big" differences in pre- and postburn abundance. Small changes might easily be an artifact of sampling methods and/or intensity.

3. We have found, often after expensive mistakes, that plant taxonomy below the species level can be important relative to vegetation management practices. The obvious case in point here involves big sagebrush, for which differences in ecosystem and therefore management implications are associated with the various subspecies (see section on "Plant Species Names"). Differences important to range management practices might also be expected of other species. Care should always be taken when extrapolating reported or observed fire effects between subspecies, varieties, and so forth.

The most common use of fire in the Intermountain region is for control of undesirable woody species of trees and shrubs: pinyon, juniper, and big sagebrush. The objective is to reduce competition with existing herbaceous plants or species that will be seeded onto the site. Species of pinyon and juniper common to the Intermountain region are not capable of resprouting after a fire and are readily removed by top-killing crown fires or when trunks are "girdled" by destruction of cambial tissue. However, the effect of fire on individual pinyon and juniper trees is dependent upon tree height, quantities of shrub and herbaceous fuels, and weather conditions. Trees less than 4 ft (1.2 m) tall are easily killed under conditions of: 600 to 1,000 lb/acre (675 to 1,125 kg/ha) fine fuels, air temperatures greater than 70° F (21° C), relative humidity 20 to 40 percent, and windspeed 10 to 20 mi/h (16 to 32 km/h) (Jameson 1962; Dwyer and Pieper 1967). Cooler temperatures and higher relative humidity can be expected to reduce mortality of this size class of trees.

Mortality of trees greater than 4 ft (1.2 m) in height requires heavy accumulations of fine fuels or continuous cover of shrubs between and below pinyon and juniper (conditions frequently difficult to meet in the Intermountain region). For the conditions listed above, Jameson (1962) and Dwyer and Pieper (1967) report kills of 13.5 to 40 percent for this size class. However, accumulations of tumbleweeds around tree bases increased crown kill to 60 to 90 percent (Jameson 1962).

Closed stands of pinyon and juniper (greater than 60 percent cover) with sparse understories are difficult to burn because fires do not readily carry (Blackburn and Bruner 1976). Crown fires are necessary to kill trees under these conditions. Ease of conducting such burns is improved with increasing crown density and as the proportion of pinyon in the stand increases.

Pure stands of juniper are nearly impossible to burn and then may require dangerously high windspeeds: in excess of 35 mi/h (56 km/h). Dense stands of mixed pinyon and juniper (500 to 1,000 trees/acre, or 1,235 to 2,470 trees/ha) can be burned on hot days (Blackburn and Bruner 1976). Bruner and Klebenow (1979) have shown that large pinyon and juniper trees can be killed in stands mixed with sagebrush under the following conditions: 45 to 60 or more percent shrub and tree cover, air temperature 60° to 75° F (16° to 32° C), relative humidity less than 25 percent, and maximum windspeed 5 to 25 mi/h (3 to 40 km/h).

Big sagebrush, a nonsprouting species, is easily killed by fire. The observed effects of fire on major shrub species in the sagebrush and pinyon-juniper zones of the Intermountain region are summarized in table 1. In general, sprouting shrubs are favored by fire. In addition to rapid postburn regrowth, many of these species, such as rabbitbrush and horsebrush, produce heavy seed crops. Thus, plant density may increase dramatically after a burn, especially on poor to fair condition range sites where the postburn community is open to establishment of new plants. Perennial herbaceous species dependent on establishment from seed appear to be much slower and therefore less competitive at expanding into these openings. Heavy seed production and ease of dispersal, both from any surviving plants and from outside the burn area, may likewise result in rapid reinvasion by big sagebrush.

Growth habit and season of burn are the principal variables regulating response of grasses to fire (table 2). In addition, effects of fire on bunchgrasses are related to culm density, culm-leaf morphology, and size of the bunch (Wright and Bailey 1982). Idaho fescue and needle-and-thread can be severely harmed by fire. This results from densely clustered, leafy culms that burn long after passage of the flaming front and irrespective of fire intensity. Late summer and fall burns appear least damaging to this growth form (Wright and Klemmedson 1965), whereas wildfires are most injurious (Countryman and Cornelius 1957). In contrast, bluebunch and crested wheatgrass and bottlebrush squirreltail are less susceptible to damage by fire. Coarse stems with lesser amounts of leafy material result in rapid combustion and little downward transfer of heat into plant crowns. Wright and Klemmedson (1965) have shown that the small basal size of Sandberg bluegrass and bottlebrush squirreltail reduce their susceptibility to injury by fire.

Rhizomatous species such as Kentucky bluegrass, thickspike wheatgrass, and many sedges are frequently favored by fire. However, burns conducted in the spring after new growth is initiated can severely injure these species. Such burns favor later-developing grasses and forbs.

Table 1. Summary of fire effects of major shrub species of the sagebrush and pinyon-juniper zones of the Intermountain region (Wright and others 1979; Volland and Dell 1981). Species with similar characteristics are grouped. See text for scientific names.

Species	Preburn regeneration	Response to fire	Postburn regeneration; recovery time[1]	Comments
Antelope bitterbrush Cliffrose	Heavy seed, animal dispersed	Moderate to severely damaged	Seed germination from rodent caches, basal stem sprouting; slow	Effect of fire on bitterbrush determined by growth form -- decumbant form may sprout vigorously, upright form is a weak sprouter. Severely damaged by summer and fall burns. Spring burns enhance sprouting; burn when wet.
Big sagebrush Black sagebrush Low sagebrush	Light seed, wind dispersed	Severely damaged	Seed germination nonsprouting; slow to rapid	Frequent, heavy seed crops; readily dispersed over large areas. Good seed production prior to burning speeds reinvasion, especially in poor condition ranges. Big sagebrush subspecies important relative to postburn community response. Black and low sagebrush rarely burn due to low fuel loads -- can be used as fuel breaks.
Threetip sagebrush	Light seed, wind dispersed	Slightly to severely damaged	Resprouts (variable), seed germination; moderate to rapid	Sprouting is strongest when burned with moist soils. Weak resprouting reported in Idaho; strong response reported in Oregon.
Silver sagebrush	Light seed, wind dispersed	Slightly damaged to unharmed	Vigorous sprouting, seed germination; moderate to rapid	May be difference in degree of resprouting between the two subspecies.
Greasewood	Light seed, wind dispersed	Slightly damaged to unharmed	Vigorous basal stem and some root sprouting; rapid	Vigorous resprouting may result in increased density of stems. Poor seed production the first year after burning. Some stands burn infrequently if at all due to low amounts of fine fuels.
Rubber rabbitbrush Green rabbitbrush Spineless horsebrush	Light seed, wind dispersed	Unharmed to enhanced	Vigorous stem sprouting, seed germination; rapid to very rapid	Reproduces abundantly from heavy seed crop, especially in low condition ranges. Rubber rabbitbrush may be more susceptible to injury, especially if burned after heavy grazing or in early summer. Horsebrush is toxic to sheep.
Broom snakeweed	Light seed, wind dispersed	Severely damaged	Seed germination, weak resprouting; moderate to rapid.	May be completely removed from an area, but new plants invade open areas rapidly by seed.
Gambel oak	Heavy seed, gravity dispersed	Enhanced	Vigorous stem and root sprouting; very rapid	Fire stimulates suckering and thickens stands. Tends to thin out when protected from fire.

(con.)

Table 1. con.

Species	Preburn regeneration	Response to fire	Postburn regeneration; recovery time[1]	Comments
Common snowberry Mountain snowberry	Rhizomes, seed	Slightly damaged to unharmed	Weak to vigorous resprouting from basal buds and rhizomes; moderate to rapid	May be enhanced by cool fires, but hot fires can damage shallow rhizomes. Mountain snowberry is a weak sprouter.
True mountain mahogany	Moderately heavy seed, wind dispersed	Slightly damaged	Vigorous sprouting, seed germination; recovery time unknown	Little information available on this species. Recovery time probably moderate to rapid, based on its sprouting response.
Curlleaf mountain mahogany	Moderately heavy seed, wind dispersed	Moderate to severely damaged	Seed germination, weak sprouting; recovery time unknown	Little information available on this species. Reported to be weak sprouter, but shoots died within 2 to 3 years. Recovery from seed probably slow to moderate.
Ninebark Ocean spray Spiraea	Light seed, wind dispersed	Unharmed to enhanced	Basal stem sprouting; moderate	Adapted to fire. Best response when burned with moist soils. Usually poor reproduction from seed.
Bittercherry Chokecherry Currant Rose Serviceberry	Heavy fleshy seed, animal	Unharmed to enhanced	Basal stem sprouting; moderate	Adapted to fire. Best response when burned with moist soils. Usually poor reproduction from seed except for currants that are heat scarified, and germination is stimulated.
Snowbrush	Heavy seed	Unharmed to enhanced	Vigorous sprouting from stems, seed is heat scarified; rapid	Seedling establishment enhanced by fall burns. Spring burns produce fewer resprouts. Common pioneer on high intensity burns.

[1]Postburn recovery time is based on the number of years required to regain preburn frequency or canopy coverage; slow >10 years, moderate = 5 to 10 years, rapid = 2 to 5 years, very rapid = 1 to 2 years.

Table 2. Summary of fire effects on major grass and grasslike species of the sagebrush and pinyon-juniper zones of the Intermountain region (Wright and others 1979; Volland and Dell 1981). Species are grouped with a genus. See text for scientific names

Species	Growth form	Response to fire	Postburn recovery time[1]	Comments
Big bluegrass	Bunchgrass	Slight to moderate damage	Rapid to very rapid	Bluegrass are mostly small bunchgrasses with densely clustered, medium to fine textured leaves. Little injury occurs with late summer or fall burns; most damage results from spring burns after initiation of growth. Heavy seed crops produced after burning.
Cusick bluegrass	Bunchgrass	Slight to moderate damage	Rapid to very rapid	
Muttongrass	Bunchgrass	Slight to moderate	Rapid to very rapid	
Nevada bluegrass	Bunchgrass	Slight damage	Rapid to very rapid	
Sandberg bluegrass	Bunchgrass	Undamaged to slight damage	Rapid to very rapid	
Kentucky bluegrass	Rhizomatous sodgrass	Slight damage	Rapid to very rapid	Increases primarily by vegetative spread.
Cheatgrass	Annual	Undamaged	Rapid to very rapid	Soil seed reserves are reduced and litter loss results in decreased plant density in the first year after fire. However, plants are large and produce abundant seed. Stand reduction is short-lived and density may exceed preburn levels within a few years.
Idaho fescue	Bunchgrass	Slight to severe	Slow to rapid	Densely tufted and fine-stemmed. Can sustain severe damage from hot summer or fall burns; but spring or fall burns with good soil moisture injure plants much less.
Indian ricegrass	Bunchgrass	Slight damage	Rapid	Slow to increase in density.
Junegrass	Bunchgrass	Undamaged	Rapid to very rapid	Small size and coarse-textured foliage result in little or no injury. Heavy seed production; may increase in density after burning.
Columbia needlegrass	Bunchgrass	Moderate damage	Moderate to rapid	Densely tufted stems make the needlegrasses one of the least fire resistant bunchgrasses. Large plants are most severely damaged; but reduction in basal area is likely among all size classes.
Needle-and-thread	Bunchgrass	Severe damage	Moderate to rapid	
Thurber needlegrass	Bunchgrass	Severe damage	Moderate to rapid	
Western needlegrass	Bunchgrass	Moderate damage	Moderate to rapid	
Douglas sedge	Rhizomatous	Undamaged	Very rapid	Response appears to be related to open growth habit and regrowth from rhizomes. Threadleaf sedge responds like fine-stemmed, densely tufted bunchgrasses.
Threadleaf sedge	Tufted bunch	Severe damage	Moderate to slow	
Bottlebrush squirreltail	Bunchgrass	Undamaged to slight damage	Rapid to very rapid	Coarse stemmed, loosely tufted. One of the most fire resistant bunchgrasses. Basal areas may be reduced from burning in dry years; but it may increase several years after burning.

(con.)

Table 2. con.

Species	Growth form	Response to fire	Postburn recovery time[1]	Comments
Bluebunch wheatgrass	Bunchgrass	Slight damage	Rapid to very rapid	Bluebunch wheatgrass is susceptible to injury when burned in dry years. Rhizomatous species may increase density. Other wheatgrasses are difficult to burn when seeded in monocultures.
Crested wheatgrass	Bunchgrass	Undamaged	Rapid	
Tall wheatgrass	Bunchgrass	Undamaged	Rapid	
Intermediate wheatgrass	Weakly rhizomatous	Undamaged	Rapid	
Thickspike wheatgrass	Rhizomatous	Undamaged	Rapid	
Western wheatgrass	Rhizomatous	Undamaged	Rapid	

[1]Postburn recovery time is based on the number of years required to regain preburn frequency or canopy coverage: slow >10 years, moderate = 5 to 10 years, rapid 2 to 5 years.

Annual grasses, including cheatgrass and medusahead, suffer reduced densities the year after a burn. This results from unfavorable microsites for germination and establishment due to loss of litter cover as well as reduction of seed reserves. Recovery is rapid, however, and densities may ultimately exceed preburn levels.

Our understanding of fire effects on forbs is less than satisfactory. With few exceptions, little work has been replicated for a species at different sites or for varying burn conditions; and no efforts have investigated response of permanently marked perennial plants. As a group, forbs respond more favorably to fire than do grasses. Additionally, late summer and fall burns occur when many forbs are dormant and/or after much of the foliage is dry and disintegrated. As noted by Wright and others (1979), the best studies of fire effects on forbs involve controlled burns in sagebrush grasslands of the upper Snake River Plains of Idaho. These studies are reported in a series of papers by Blaisdell (1953), Pechanec and others (1954), and Harniss and Murray (1973). Their findings are summarized in table 3. Species uninjured or slightly injured by fire were those that spread by rootstalks or short shoots (Pechanec and others 1954). These increased most rapidly after burning. Arrowleaf balsamroot and tailcup lupine, although undamaged by fire, were slow to increase after burning. Annual species are also capable of rapid increases in abundance following burning (see also Piemeisel 1938; Barney and Frischknecht 1974; Young and Miller 1983). Forbs most severely harmed by fire included species with suffretescent growth forms.

FIRE EFFECTS ON SOIL

The long-held notion that fire damages soils of range ecosystems has largely been laid to rest through findings of research over the past 30 years. Although combustion of plant materials results in volatilization of nitrogen and sulfur, most nutrients are added directly to the soil surface as soluble salts (Daubenmire 1968). These are readily available for uptake by plants. In most instances both total and available soil nitrogen are observed to increase after burning. This is primarily due to stimulation of nitrogen-fixing bacteria associated with legumes and nonlegume (such as snowbrush) plants and increased rates of organic matter decomposition (Sharrow and Wright 1977). Increased soil temperatures, soil water, and nutrient availability after a burn are frequently manifest in increased production of herbaceous plants.

Nutrients not leached into the soil are subject to loss through wind and/or water erosion. This is the principal concern relative to fire-soil interaction when using controlled burning in rangeland communities. Buckhouse and Gifford (1976) found increased levels of phosphorus and potassium in runoff of simulated rainfall following slash pile burning in a pinyon-juniper community. Quantities of nitrate-nitrogen, sodium, and calcium were unchanged. However, due to low annual precipitation, the use of fire in sagebrush and pinyon-juniper communities does not generally affect erosion or runoff rates except after 25-year storms or on slopes exceeding 30 to 45 percent (Blaisdell and others 1982; Wright and Bailey 1982). Soil losses due to wind

Table 3. Summary of relative response to fire of forbs in sagebrush grasslands of the upper Snake River Plains of Idaho (Pechanec and others 1954). See text for scientific names.

Severely damaged	Slightly damaged	Undamaged
Hairy fleabane	Astragalus	Arrowleaf balsamroot
Hoary phlox	Matroot penstemon	Common comandra
Littleleaf pussytoes	Monroe globemallow	Common sunflower
Low pussytoes	Pinnate tanseymustard	Coyote tobacco
Mat eriogonum	Plumeweed	Douglas knotweed
Unita sandwort	Red globemallow	Flaxleaf plainsmustard
Wyeth eriogonum	Sticky geranium	Flixweed tanseymustard
	Tailcup lupine	Foothill deathcamas
	Tapertip hawksbeard	Gayophytum
	Tongueleaf violet	Goldenrod
	Tumblemustard	Goosefoot
	Wavyleaf thistle	Lambstongue groundsel
	Whitlow-wart	Longleaf phlox
	Wild lettuce	Orange arnica
		Pale alyssum
		Purpledaisy fleabane
		Russian thistle
		Velvet lupine
		Western yarrow
		Wild onion

erosion are also a potential hazard. This is especially true of sandy soils, as has been reported by Blaisdell (1953).

APPLICATION OF PRESCRIBED BURNING

Much of the following material, especially the burning prescriptions, has been taken from the more detailed treatments in Wright and others (1979) and Wright and Bailey (1982).

The Sagebrush Zone

The primary use of fire in the sagebrush zone of the Intermountain region is to control dense stands of sagebrush for the purposes of increasing herbaceous production and increasing habitat diversity. The following guidelines are intended to assist in planning and conducting prescribed burns in this major vegetation type.

Where to burn.--Sparse vegetal cover generally precludes the use of prescribed fire in dwarf sagebrush habitat types. Furthermore, fire may be undesirable where valuable browse species such as black sagebrush or low sagebrush occur (Blaisdell and others 1982). The potential use of prescribed burning is greatest in habitat types dominated by the three subspecies of big sagebrush (basin, Wyoming, and mountain big sagebrush), threetip sagebrush, and mountain silver sagebrush.

Results of prescribed burning have not been reported for mountain silver sagebrush communities. Therefore, guidelines for using fire in this type are not available. These sites typically have high productive potential, however, and should be considered as candidate areas for using fire.

Burning sagebrush ranges generally requires a minimum of 600 to 700 lb/acre (650 to 750 kg/ha) of herbaceous fuels and approximately 20 percent or more sagebrush cover (Beardall and Sylvester 1976; Britton and Ralphs 1979). Pechanec and others (1954) suggest that burning should be considered only where sagebrush forms at least 30 percent of the total plant cover. Many sagebrush sites will therefore be difficult or impossible to burn: degraded stands often produce far less than the necessary amount of fine fuels; and similarly, shrub cover is frequently below the minimum levels required. This is especially true of many Wyoming big sagebrush dominated areas. In general, the more xeric the site, the more difficult it will be to obtain consistent results when using prescribed burning for shrub control.

Where stands of sagebrush are sufficiently dense or when forbs are abundant in the community, controlled burning is preferred to herbicide application for site improvement. Caution is advised in using fire where bitterbrush occurs in significant quantities due to its susceptibility to damage by fire. Conversely, where rabbitbrush or horsebrush are abundant, fire can result in increased density and cover of these species in the postburn community, especially in stands of poor to fair condition.

Controlled burning should be restricted to areas with sufficient cover of fire-tolerant grasses and forbs or where subsequent seeding is practicable (Blaisdell and others 1982). A precise definition of "sufficient" cannot be given. As a general rule, though, desirable species should make up 20 percent or more of the plant cover; or, where bunchgrass density is at least one plant per square yard (about one plant/m^2). Irrespective of plant cover, fire should not be used where soils are unstable or on slopes exceeding 30 percent.

Burning followed by seeding will suppress stands of medusahead. However, only limited success has been achieved with this technique in dense cheatgrass (for exceptions see Hull and Stewart 1948; Young and Miller 1983). In mixed sagebrush-cheatgrass stands, seeding after burning has been successful where cheatgrass seed reserves are reduced by 80 to 90 percent. In either situation, where sufficient seed survives the burn, chemical fallow or plowing after emergence of cheatgrass seedlings may be necessary before seeding is attempted.

Livestock are likely to concentrate on burned areas resulting in overuse of this portion of a pasture. This can be prevented by burning entire pastures or by fencing the burn area for use as a separate management unit.

When to burn.--The principal times recommended for conducting prescribed burns on sagebrush ranges are early fall and spring. Most consistent results are achieved with fall burns conducted prior to the advent of cool, moist weather. Most nontarget species are dormant at this time, and fire-induced damage should be within acceptable limits when low to medium intensity burns are carried out.

The limitation of spring burning is timing: favorable burning conditions typically occur for only short periods. In addition to necessary weather conditions, fine fuels must be sufficiently dry and yet burns should be conducted prior to greenup of desirable herbaceous species. However, when successfully carried out, early spring burning will usually control sagebrush with minimal damage to other species.

Midsummer burning is not a recommended practice due to the susceptibility of forage species, especially bunchgrasses, to damage. Furthermore, control problems are greatest during the hot, dry conditions prevalent in this season. Late summer burning may be advisable when the area is planned for fall seeding.

How to burn.--Except where shrub coverage is very dense, livestock grazing must be excluded from areas to be burned for the entire growing season prior to treatment. This is to provide adequate fine fuels to carry the fire.

Based upon economic analyses of various size burns in sagebrush-grasslands, Davis (1977) suggests that most efficient burn units are of about 450 acres (180 ha). However, as mentioned previously, when burn areas cannot be separately fenced, entire

management units should be burned. This may best be accomplished by dividing a pasture into several units that will be burned independently.

In sagebrush-grass vegetation Wright and others (1979) and Wright and Bailey (1982) suggest the following burn prescription:

1. A fireline of 10 to 12 ft (3.0 to 3.7 m) width should be dozed around the entire area to be burned.

2. During the morning hours, use strip headfires to construct a 250 ft (75 m) blackline along the downwind boundaries. Air temperature should be 60° to 70° F (16° to 21° C), relative humidity 25 to 40 percent, and windspeed 6 to 10 mi/h (8 to 16 km/h). At 250 ft (75 m), backing fires can be stopped with a pumper or by placement of another dozer line.

3. In early afternoon, as weather conditions are approaching daily maximum air temperatures and minimum relative humidity, headfire the remaining area. Recommended conditions include air temperature of 75° to 85° F (24° to 29° C), relative humidity 15 to 20 percent, and windspeed 8 to 15 mi/h (13 to 24 km/h).

Major disadvantages associated with sagebrush burning are the cost of construction and undesirable effects of bulldozed firelines. These problems may be eliminated or minimized where natural firebreaks are used. Stands of big sagebrush surrounded by low sagebrush can be safely burned without preparation of firelines because fire rarely spreads through this latter type even under high temperatures and windspeeds up to 25 mi/h (40 km/h) (Beardall and Sylvester 1976). Snowbanks may also be used as firelines when conducting spring burns. Beardall and Sylvester (1976) suggest that early spring burning can be carried out in areas with greater than 600 lb/acre (650 kg/ha) of fine fuels when relative humidity is less than 60 percent and windspeed is greater than 8 mi/h (13 km/h). Britton (personal communication) suggests firelines can be constructed with heavy grazing around the burn unit to remove herbaceous fuels prior to burning. With sufficiently low sagebrush cover, the flame front dies as it passes into the area where fine fuels have been reduced by grazing.

Postburn management.--Proper grazing management following prescribed burning is required to realize the potential benefits of this treatment. Grazing should not be permitted for at least one and possibly two growing seasons after the burn. This will allow native herbaceous species to regain vigor and take advantage of the increased availability of water and nutrients. Heavy seed crops are often produced by grasses and forbs during this period. Therefore, it may be desirable to permit light grazing in late summer or fall (after seed dispersal) to improve seed germination and establishment of new plants.

Because sagebrush is a natural component of the vegetation in this region, these rangelands cannot be kept entirely free of sagebrush. Reinvasion may occur with the best of management efforts. Furthermore, eliminating sagebrush from these areas may not be desirable. As sagebrush density increases, however, production of forage species will decline. Under these circumstances repeated burning at intervals of 20 to 30 years should maintain the range in satisfactory condition.

Burning cheatgrass ranges.--Prescribed burning of cheatgrass ranges should always be followed by artificial seeding as native species will rarely increase rapidly enough (if at all) to accomplish management objectives. Firelines can usually be constructed using the wetline technique developed by Martin and others (1977). Fires are backed away from a single wetline or allowed to burn out between two parallel wetlines.

Martin and others (1982) recommended the following prescription for burning cheatgrass ranges:

1. Burns may be conducted any time after annual grasses are cured and until fall weather prohibits burning. Burn at least 3 days after precipitation to allow litter to dry and thus insure high seed mortality.

2. Weather conditions should consist of air temperature 56° to 84° F (10° to 30° C), relative humidity 20 to 45 percent, and windspeed 0 to 10 mi/h (0 to 15 km/h).

3. Backing fires should be initiated at the downwind lines and combined with strip headlines to develop a 30 to 100 ft (10 to 30 m) blackline Headfire the remainder of the unit. Center or ringfiring can be used under conditions of no wind.

The Pinyon-Juniper Zone

The primary uses of fire in pinyon-juniper woodlands are (1) to reduce woody trees and shrubs, allowing recovery of native herbaceous species or/to permit subsequent artificial seeding; and (2) to increase habitat diversity where the pinyon-juniper type is continuous over extensive areas. The following guidelines are provided for planning and conducting prescribed burns in the different pinyon-juniper types of the Intermountain region. Again, this material follows the discussion and recommendations found in Wright and others (1979) and Wright and Bailey (1982).

Closed pinyon-juniper (sparse understory).--Dense stands of pinyon-juniper with little or no shrubs and grasses in the understory are difficult to burn. To significantly improve these sites, prescribed burning must often be used in combination with mechanical treatment, such as chaining, and followed by seeding. Without prior treatment, burning can only be carried out under conditions of high temperatures, low relative humidity, and moderate to high windspeed; that is, when fire control will almost certainly be difficult. Although expensive, mechanical treatment followed by burning and/or seeding is a viable means of converting closed pinyon-juniper woodlands to productive shrub-grass mixtures.

The following prescription is recommended for burning in closed stands of pinyon-juniper.

1. A 10 ft (3 m) dozer line should be placed around the burn area, including parallel lines

500 ft (150 m) apart along the downwind boundaries. The downwind strips can be chained and the debris windrowed in the winter or at any prior time.

2. Windrows within these strips are then burned in early spring or summer when vegetation of adjacent areas is still green. Conditions at this time should include air temperatures of 60° to 75° F (16° to 24° C), relative humidity 20 to 35 percent, and windspeed 0 to 10 mi/h (0 to 16 km/h).

3. The main portion of the burn area is prepared in the spring by dozing strips 20 to 50 ft (6 to 15 m) wide every 0.25 mi (0.4 km) and pushing the debris against the windward side of the standing trees. These fuels should be allowed to cure for 2 to 3 months.

4. Burning can then be conducted in the summer with air temperatures of 80° to 95° F (27° to 35° C), relative humidity less than 10 percent, and windspeed greater than 8 mi/h (13 km/h). The dozed fuels are ignited on the upwind side. The burning debris builds sufficiently high fire intensity that, in combination with the winds, a crown fire will carry through the standing green trees.

Nearly pure stands of juniper are difficult to burn unless they have been chained. Firelines are constructed as above except that downwind strip width need only be 250 ft (75 m) wide. Piles and windrows within the strips are burned when air temperature is 65° to 75° F (18° to 24° C), relative humidity 15 to 25 percent, and windspeed 8 to 10 mi/h (13 to 16 km/h). The main portion of the burn area is burned any time after chained fuels have cured 2 to 3 months and when air temperature is 90° to 100° F (32° to 38° C), relative humidity is less than 10 percent, and windspeed is 8 to 10 mi/h (13 to 16 km/h). Because it is often impossible to broadcast burn these sites, large crews may be necessary to ignite the scattered piles and windrows of juniper debris.

Mixed pinyon-juniper shrub.--Pinyon-juniper woodlands of the Intermountain region support variable amounts of shrubs, the most common and abundant of which is sagebrush. Bruner and Klebenow (1979) have shown that dense, mixed pinyon-juniper-shrub stands can be burned without firelines. They have developed a simple index to determine when and where these burns should be attempted. The components of this index are total tree and shrub cover, air temperature, and maximum windspeed. The relationship of these variables and the conditions under which burning is possible are as follows:

INDEX = tree and shrub cover (%)
+ air temperature (°F)
+ maximum windspeed (mi/h)

where, shrub and tree cover = 45 to 60 percent, air temperature = 60° to 75° F (16° to 24°C), windspeed = 5 to 25 mi/h (8 to 40 km/h), and relative humidity = less than 25 percent. The index must equal or exceed 110 for a fire to carry and kill large pinyon and juniper trees. However, at values less than 125, reignition of trees may be necessary. Above 130, conditions are too hazardous to burn.

This method is most useful for burning dense patches of pinyon-juniper-shrublands. However, due to the discontinuity of fuels on these sites, burning of large areas is usually not possible. Using this approach, Bruner and Kelbenow (1979) have burned areas varying in size from 5 to 60 acres (2 to 24 ha). Burned sites may be left to reseed naturally or may be aerially seeded.

Postburn management.--Burning can be used to release existing desirable plants from competition with pinyon and juniper. The guidelines presented earlier should be used in deciding if an adequate response might be expected. In many cases it will be necessary to artificially seed burned areas so that the productive potential of a site is realized. Species selection and seeding techniques applicable to the pinyon-juniper and sagebrush zones are discussed in other portions of these proceedings. Postburn grazing management should follow the recommendations given for sagebrush communities.

PLANT SPECIES NAMES

Common and scientific names of some of the plant species in the sagebrush and pinyon-juniper zones of the Intermountain region.

Common name	Scientific name
TREES	
Juniper	*Juniperus monosperma*, *J. osteosperma*, *J. scopulorum*
Pinyon pine	*Pinus edulis*, *P. monophylla*
SHRUBS	
Antelope bitterbrush	*Purshia tridentata*
Big sagebrush	*Artemisia tridentata*
- basin	ssp. *tridentata*
- mountain	ssp. *vaseyana*
- Wyoming	ssp. *wyomingensis*

Bittercherry	Prunus emarginata
Black sagebrush	Artemisia arbuscula nova
Broom snakeweed	Xanthocephalum sarothrae
Chokecherry	Prunus virginiana
Cliffrose	Cowania mexicana stansburiana
Common snowberry	Symphoricarpos albus
Curlleaf mountain mahogany	Cercocarpus ledifolius
Currant	Ribes spp.
Gambel oak	Quercus gambelii
Greasewood	Sarcobatus vermiculatus
Green rabbitbrush	Chrysothamnus viscidiflorus
Low sagebrush	Artemisia arbuscula arbuscula
Mountain silver sagebrush	Artemisia cana ssp. viscidula
Mountain snowberry	Symphoricarpos oreophilus oreophilus
Ninebark	Physocarpus malvaceus
Oceanspray	Holodiscus discolor
Rose	Rosa spp.
Rubber (grey) rabbitbrush	Chrysothamnus nauseosus
Serviceberry	Amelanchier alnifolia
Snowberry	Ceanothus velutinus
Spineless horsebrush	Tetradymia canescens
Spirea	Spiraea betulifolia
Threetip sagebrush	Artemisia tripartita ssp. tripartita
True mountain mahogany	Cercocarpus montana

GRASSES AND SEDGES

Big bluegrass	Poa ampla
Bluebunch wheatgrass	Agropyron spicatum
Bottlebrush squirreltail	Sitanion hystrix
Cheatgrass	Bromus tectorum
Columbia needlegrass	Stipa columbiana
Crested wheatgrass	Agropyron cristatum, A. desertorum
Cusick bluegrass	Poa cusickii
Douglas sedge	Carex douglasii
Idaho fescue	Festuca idahoensis
Indian ricegrass	Oryzopsis hymenoides
Intermediate wheatgrass	Agropyron intermedium
Junegrass	Koeleria cristata
Kentucky bluegrass	Poa pratensis
Medusahead	Taeniatherum asperum
Muttongrass	Poa fendleriana
Needle-and-thread	Stipa comata
Nevada bluegrass	Poa nevadensis
Sandberg bluegrass	Poa sandbergii
Tall wheatgrass	Agropyron elongatum
Thickspike wheatgrass	Agropyron dasystachum
Threadleaf sedge	Carex filifolia
Thurber needlegrass	Stipa thurberiana
Western needlegrass	Stipa occidentalis
Western wheatgrass	Agropyron smithii

FORBS

Arrowleaf balsamroot	Balsamorhiza sagittata
Astragalus	Astragalus spp.
Common comandra	Comandra umbellata
Common sunflower	Helianthus annus
Coyote tobacco	Nicotiana attenuata
Douglas knotweed	Polygonum douglasii
Flaxleaf plainsmustard	Sisymbrium linifolium
Flixweed tanseymustard	Descurainia sophia
Foothill deathcamas	Zygadenus paniculatus
Gayophytum	Gayophytum diffusum
Goldenrod	Solidago spp.
Goosefoot	Chenopodium spp.
Hairy fleabane	Erigeron concinnus
Hoary phlox	Phlox canescens
Lambstongue groundsel	Senecio integerrimus

Littleleaf pussytoes	*Antennaria microphylla*
Longleaf phlox	*Phlox longifolia*
Low pussytoes	*Antennaria dimorpha*
Mat eriogonum	*Eriogonum caespitosum*
Matroot penstemon	*Penstemon radicosus*
Northwestern paintbrush	*Castilleja angustifolia*
Orange arnica	*Arnica fulgens*
Pale alyssum	*Alyssum alyssoides*
Pinnate tanseymustard	*Descurainia pinnata*
Plumeweed	*Cordylanthus ramosus*
Purpledaisy fleabane	*Erigeron corymbosus*
Red globemallow	*Sphaeralcea coccinea*
Russian thistle	*Salsola pestifer*
Sticky geranium	*Geranium viscosissimum*
Tailcup lupine	*Lupinus caudatus*
Tapertip hawksbeard	*Crepis acuminata*
Tongueleaf violet	*Viola nuttallii*
Tumblemustard	*Sisymbrium altissimum*
Uinta sandwort	*Arenaria utahensis*
Velvet lupine	*Lupinus leucophyllus*
Wavyleaf thistle	*Cirsium undulatum*
Western yarrow	*Achillia millefolium*
Whitlow-wart	*Draba verna*
Wild lettuce	*Lactuca* sp.
Wild onion	*Allium* sp.
Wyeth eriogonum	*Eriogonum heracleoides*

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THE APPLICATION AND USE OF HERBICIDES FOR BRUSH AND WEED CONTROL

R. A. Evans, J. A. Young, and R. E. Eckert, Jr.

ABSTRACT: Use of herbicide provides effective and efficient control of brush and herbaceous weeds in the management of the sagebrush-grass ecosystem. Rabbitbrush and other root or crown-sprouting shrubs are harder to control than sagebrush and require careful timing of spraying or a wider spectrum of herbicides. Techniques have been developed for control of downy brome and other herbaceous weeds when seeding perennial grasses for improvement of degraded sagebrush rangelands. Weed control-seeding systems, involving control of brush and herbaceous weeds plus seeding of forage and browse species, have been successful in the conversion of degraded communities to stable, high-producing rangelands.

INTRODUCTION

The sagebrush-grass ecosystem is the largest rangeland type in the western United States. In the Great Basin and Northwest subregion, which includes most of northern Nevada and parts of Utah, Idaho, Oregon, and Washington, there are almost 85 million acres (35 million ha) of sagebrush-grass rangeland (Evans and others 1981). Of these rangelands, 88 percent, almost 75 million acres (30 million ha) are degraded to the point that they are producing 50 percent or less of their forage potential (Forest Service 1972). Only 1 percent of the over 4 million acres (1.6 million ha) of sagebrush-grass rangelands in the Humboldt River Basin of northeastern Nevada are in the high forage production class (Anonymous 1966).

Low forage production on these rangelands has been caused by overgrazing and other past land abuses (Young and others 1979) resulting in a severe depletion of native perennial grasses, a dominance of brush, and in many instances, annual alien weed dominance in the understory.

Once big sagebrush (*Artemisia tridentata*) becomes established as the dominant species of degraded sagebrush-grass rangelands, it is persistent enough to stabilize succession in these communities for long periods. This tenure of dominance has not been determined, but the life expectancy of big sagebrush may exceed 150 years (Ferguson 1964). Degraded rangelands dominated by big sagebrush can remain static, producing virtually no forage for decades regardless of grazing management or even without livestock grazing.

R. A. Evans, J. A. Young, and R. E. Eckert, Jr. are Range Scientists at the Renewable Resource Center, University of Nevada, Reno, Nev.

MAJOR BRUSH SPECIES

By far the most abundant brush species of the sagebrush-grass rangelands is big sagebrush with its three subspecies *tridentata*, *wyomingensis*, and *vaseyana*. On specific sites other species of sagebrush dominate, e.g. low sagebrush (*A. arbuscula*) and alkali sagebrush (*A. longiloba*) usually occur on shallow soils, black sagebrush (*A. nova*) usually is associated with carbonate soils, and silver sagebrush (*A. cana*) is found primarily on wet sites.

Representing seral stages after disturbances and on many sites occurring as either codominant or subdominant with big sagebrush are green and gray rabbitbrush (*Chrysothamnus viscidiflorus* and *C. nauseosus*) and horsebrush (*Tedradymia canescens*). Other brush species occurring in some stands are species of *Ribes*, *Ephedra*, and *Prunus*.

HERBICIDES AND THEIR APPLICATION FOR BRUSH CONTROL

What to Spray

The discovery of 2,4-D [(2,4-dichlorophenoxy) acetic acid] as a plant growth regulator in 1942 began the development of synthetic hormones for weed control (Bovey 1971).

After World War II, several scientists independently recognized the potential of 2,4-D in controlling sagebrush for the release of perennial grasses. This herbicide is currently registered by the Environmental Protection Agency (EPA) for use on sagebrush-grass rangelands.

Among the first to demonstrate the effectiveness of 2,4-D for controlling big sagebrush were Elwell and Cox (1950), Cornelius and Graham (1951), and Hull and Vaughn (1951). Working independently, Hyder (1953) demonstrated its usefulness in eastern Oregon, and Bohmont (1954) and Hull and others (1952) demonstrated its usefulness in Wyoming. Gradually, guidelines were developed to help ensure the success of spray application. As the brush control program with 2,4-D became widespread, there were a few failures, almost all of which can be traced to violations of the initial guidelines.

Although 2,4-D is very effective in controlling sagebrush, other brush species either occurring alone or in mixed stands with sagebrush are more resistant to this herbicide. Effective control of green rabbitbrush by 2,4-D requires careful timing of application in relation to its phenology, air temperature, and available

soil moisture. There are some years when 2,4-D cannot adequately control green rabbitbrush or when the period of susceptibility is so short that only small areas can be treated. These problems have been lessened by the use of more recently developed herbicides that translocate better and control green rabbitbrush more effectively than 2,4-D. Also, additional research is warranted on improving efficacy of 2,4-D for brush control with improved application technology relative to equipment modifications; use of different total volumes of spray, and improved surfactants, additives and carriers; and the use of remote sensing to more accurately predict the periods of optimum susceptibility.

The most effective and widely tested of the alternative herbicides has been picloram (4-amino-3,5,6-trichloropicolinic acid). Relatively low rates of picloram have been shown to be extremely effective for control of green rabbitbrush (Tueller and Evans 1969; Cook and others 1965). Picloram does not control big sagebrush at these rates, so 2,4-D must be applied with the picloram for control of both species. Picloram has not been marketed as a mixture with low-volatile esters (l.v.e.) of 2,4-D. Tank mixtures of potassium salts of picloram and l.v.e. of 2,4-D have been effective in aerial applications to mixed stands of green rabbitbrush and big sagebrush (Evans and Young 1975).

Picloram has been registered for application either alone or in tank mixtures with 2,4-D for control of rabbitbrush and other brush species on rangelands by EPA with a Special Local Needs Label for Idaho, Nevada, Oregon, Utah, and Washington. A Supplemental Use Label has been issued for control of weed and brush species, including rabbitbrush, in Wyoming.

Tebuthiuron (N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2yl] -N, N^{1}-dimethylurea] and dicamba (3,6-dichloro-anisic acid) are both registered for brush control on rangelands by EPA but there are very few publications verifying their efficacy in the sagebrush-grass rangelands. Britton and Sneva (1981) indicated that frequencies of big sagebrush and low sagebrush were severely reduced by 1.8 lb/acre (2 kg/ha) of tebuthiuron (20 percent a.i. pellets) and green rabbitbrush was virtually eliminated by 3.6 lb/acre (4 kg/ha). At these rates, accompanying perennial grasses were also damaged.

Further studies in Oregon with tebuthiuron at lower rates indicate control of big sagebrush of 80 percent with 0.87 lb/acre (1 kg/ha), 58 percent with 0.75 lb/acre (0.8 kg/ha), and 35 percent with 0.5 lb/acre (0.6 kg/ha) a.i. of the 20 percent pellets, respectively[1/]. No significant damage was seen on perennial grasses when tebuthiuron was applied at these rates. At this time, 2,4-D is the principal and the most practical herbicide for brush control on sagebrush-grass rangelands. Big sagebrush is usually controlled by 2 lb/acre (2.2 kg/ha) of 2,4-D. With mixed stands of sagebrush and green rabbitbrush control can be effective with either 3 lb/acre (3.4 kg/ha) of 2,4-D or a mixture of 0.5 lb/acre (0.6 kg/ha) of picloram and 2 lb/acre (2.2 kg/ha) of 2,4-D.

Where to Spray

The choice of the proper site for a spray application is the most important factor in ensuring the success of the herbicide treatment as a range improvement practice. It does no good to kill the brush if no perennial grasses are available to take advantage of the released environmental potential (Alley 1956). Hyder and Sneva (1965) developed the rule-of-thumb that only if one could step from plant to plant of desirable perennial grass species, would there be enough perennials to permit a forage response and to prevent the invasion of annual grasses or other desirable species.

The best sites to spray are old, even aged, stands of big sagebrush with many mature plants. Errors can be made by spraying sites of low sagebrush and expecting them to be as productive as big sagebrush sites. Eckert and others (1972) reported an average increase of 436 lb/acre (488 kg/ha) total forage production at nine locations in northern Nevada with low sagebrush control of 96 to 100 percent. Errors can be made by spraying sites with desirable species such as bitterbrush (*Purshia tridentata*), which can lead to confrontations between range managers and wildlife biologists. These confrontations are unnecessary, because careful selection of sites to be sprayed can prevent them. Also, by application of timing techniques developed by Hyder and Sneva (1962), big sagebrush can usually be removed from a site without killing the desirable bitterbrush.

Errors were also made in choosing sites with large populations of green or gray rabbitbrush or horsebrush. These root-sprouting species are relatively difficult to control, and improper application of 2,4-D to sites with these species often released them from competition by big sagebrush (Robertson and Cords 1957).

When to Spray

Big sagebrush is most susceptible to 2,4-D when it is growing rapidly in the spring. Because big sagebrush has persistent leaves, its phenology is difficult to measure. Hyder (1954) used the phenology of the native perennial grass, Sandberg bluegrass (*Poa sandbergii*) to estimate the correct time for applying herbicides. He concluded that the correct time for spraying in eastern Oregon extended from the heading of Sandberg bluegrass until one-half of the green color was gone. Measurements of soil moisture were determined to be important in estimating the correct time for herbicide application, which generally was the month of May. However, on shallow soils or south slopes, the correct application time may

[1] Miller, R. Burns, OR: Data on file at USDA Agriculture Research Service.

be earlier and of much shorter duration and in wet years it may be later and of much longer duration.

In Wyoming a more reliable way of estimating the correct timing of herbicide application was from the phenology of big sagebrush itself rather than reliance on that of other species (H. P. Alley, personal communication).

As was previously noted, species of rabbitbrush are more difficult to control with 2,4-D than big sagebrush. Hyder and others (1958, 1962) determined that application must be carefully timed for adequate control of rabbitbrush. The current annual growth of the shoots must reach 3 inches (7.6 cm) and soil moisture must be available if the herbicide is to be effective. The length of time that green rabbitbrush is susceptible to 2,4-D varies greatly among years and location. The period of susceptibility may equal that of big sagebrush or it may not occur at all.

In mixed stands of big sagebrush and rabbitbrush, herbicide application should be timed with the phenology of rabbitbrush because of its usually shorter period of susceptibility.

Prediction of the optimum date for application of 2,4-D to green rabbitbrush is essential because herbicide-mixing facilities, aircraft, and flagging crews must be prepared in advance if they are to be ready for the application at the often remote sites by the chosen date.

Prediction is complicated by the phenology pattern of growth for green rabbitbrush, in which 40 percent of the current year's growth can occur within 2 weeks before the optimum application date (Young and Evans 1974b). Prediction is further complicated by the interaction of age and competition on the growth rate and phenology of green rabbitbrush. Young stands grow faster than old stands that are competing with big sagebrush plants.

Color infrared photography can be used to predict the optimum spray date for green rabbitbrush (Evans and others 1973; Young and others 1976). This method has the advantage of enabling the collection of large, statistically precise samples from remote areas in a very short time. A single trained interpreter can predict the optimum application date from photographs and return a recommendation within 24 hours.

How to Spray

Aerial applications of 2,4-D are the most practical to control big sagebrush on large areas. Prevailing recommendations today are to spray 2 lb/acre (2.2 kg/ha) of low volatile esters of 2,4-D in 5 gal/acre (47 l/ha) of water for big sagebrush control. When green rabbitbrush occurs in the stand it is necessary to increase the rate of 2,4-D to 3 lb/acre (3.3 kg/ha) for acceptable control.

Original recommendations called for the butyl or isopropyl ester to be applied at 1.0 to 1.5 lb a.i./acre (1.1 to 1.7 kg a.i./acre) with sufficient water for application at 5 gal/acre (47 l/ha). Low-volatile esters were recommended where big sagebrush was hard to control. Some range managers preferred diesel oil to water as a carrier, but the increase in efficiency of weed control seldom justified the increase in cost.

In an assessment of spraying for control of big sagebrush in the Vale project in southeastern Oregon, Heady and Bartolome (1977) concluded that no clear-cut advantage was gained by the use of oil as a carrier. However, many land managers and some scientists (H. P. Alley, personal communication) strongly believe that oil is a better carrier than water for applying 2,4-D to big sagebrush.

Errors made in spraying for big sagebrush control include improper mixing of the herbicide and carrier, flying too high or fast, and improper marking of sites to be sprayed during herbicide application (Pechanec and others 1965). Such errors are probably less important than errors in the timing of spraying (F. A. Sneva, personal communication).

To spray small areas or places remote form agricultural areas where aerial applicators may be difficult to obtain, a ground sprayer for herbicide application may be more practical than aerial application. Young and others (1979) have modified readily available power-ground sprayers to permit their use on sagebrush rangelands.

TENURE OF GRASS DOMINANCE AFTER RELEASE

How long do perennial grasses remain dominant after release from shrub competition? This is one of the most perplexing questions involved in economic evaluations of the use of herbicides for brush control in sagebrush/grasslands (Johnson 1969; Sneva 1972). Some grass communities are reinvaded by shrubs almost immediately after brush control. Very few stands have remained virtually shrubfree for years (Weldon and others 1958). Sneva (1972) believed that sagebrush control in the Great Basin lasts longer than sagebrush control from similar treatments in Wyoming because of the intense summer drought in the Great Basin, which limits seedling establishment of shrubs. Other scientists believe that Johnson's (1969) estimate of the useful life of sprayed areas in Wyoming was too short, because the stands he studied did not initially have complete shrub control (H. P. Alley, personal communication).

Competition between big sagebrush and perennial grasses has been studied for many years (Robertson and Pearse 1945; Blaisdell 1948; Cook 1958). Working with crested wheatgrass (Agropyron desertorum) and Wyoming big sagebrush (A. tridentata subsp. wyomingensis), Rittenhouse and Sneva (1976) reported that perennial grass production declined 3.3 to 5.7

percent for every 1 percent increase in brush crown cover.

On public lands, the maintenance of mixed stands of perennial grasses, forbs, and shrubs is a goal of multiple-use management, even though maximum forage production may result only with minimum density of big sagebrush. In keeping with this goal, the guidelines of most public land management agencies specify that spraying of big sagebrush is to provide only incomplete control of shrubs. The goal is desirable, but the methodology for achieving it may be faulty. Studies by Young and Evans (1974a) have shown that partial control of shrubs (15 to 65 percent) can lead to dramatic increases in shrub density through increased seed production and seedling establishment. Almost complete control of shrubs (85 to 98 percent) on some areas with no control on adjacent ones may be a more effective alternative. The dynamics of both partial control of shrubs in relation to perennial grass density and the post-treatment invasion of shrubs into grass-dominated communities are aspects of sagebrush/grasslands ecology that merit further study.

HERBACEOUS WEEDS

Within the sagebrush/grasslands, control of herbaceous weeds is predominantly the control of alien annuals to allow the establishment of seedlings of desirable perennials. The secondary successional role of native herbaceous species has been almost entirely preempted by downy brome (Bromus tectorum) and associated alien species (Piemeisel 1938).

Sites dominated by downy brome are largely closed to the establishment of perennial grass seedlings (Robertson and Pearse 1945). Attempts to introduce wheatgrass in downy brome sites by seeding generally have failed unless the site was first fallowed by mechanical methods (Hull and Holmgren 1964).

The alien annual grass medusahead (Taeniatherum asperum) has invaded portions of Oregon, California, Washington, and Idaho (Young and Evans 1970). Medusahead invasion in the sagebrush/grasslands is largely restricted to low sagebrush sites (Young and Evans 1971).

Paraquat

The herbicide paraquat (1,1'-dimethyl-4, 4'-bipyridinium ion) was first used for downy brome control on sites to be reseeded because of its relatively unique characteristic of being deactivated upon absorption to the soil. This characteristic permits the spraying of paraquat at 0.5 to 1.0 lb/acre (0.6 to 1.1 kg/ha) and the immediate seeding of wheatgrasses (Evans and others 1967). Paraquat is registered by EPA for specific use on sagebrush rangelands. It is a restricted-use herbicide because of its high mammalian toxicity. Proper care must be exercised in its use.

If in the annual community being treated with paraquat contained tumble mustard (Sisymbrium altissimum) 2,4-D at 0.5 lb/acre (0.6 kg/ha) was added for control of this species. Paraquat, a contact herbicide, must be applied after the downy brome has emerged. In most of the sagebrush/grasslands this makes spring seeding necessary.

Under the environmental conditions of the sagebrush/grasslands, it is difficult to consistently control downy brome with aerially applied paraquat even though ground applications are always effective. The addition of proper surfactants enhances the effectiveness of ground applications of paraquat (Evans and Eckert 1965).

Atrazine Fallow

After evaluating large numbers of soil-active herbicides, Evans and others (1969) determined that atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine] was the best candidate for creating herbicidal fallows. The characteristics evaluated were spectrum of weed control, consistency of performance among years and amount of herbicide residue 1 year after application.

The atrazine-fallow technique was developed (Eckert and Evans 1967) and tested extensively (Eckert and others 1974). Atrazine is registered by EPA for specific uses on sagebrush rangelands. The atrazine is applied at 1.0 lb/acre (1.1 kg/ha) in the fall and a fallow is created during the next growing season. The area is seeded to wheatgrasses 1 years after the herbicide is applied. The amount of herbicide residue that is present at the time of seeding is critical in the success of seedling establishment (Eckert and others 1972; Eckert 1974). Seedling success is enhanced by seeding wheatgrasses in the bottom of furrows made with a modified rangeland drill (Asher and Eckert 1973). The furrow provides a favorable microenvironment for seedling establishment (Evans and others 1970) and removes herbicide residues on the soil surface to the area between the furrows.

The atrazine-fallow technique works equally well on medusahead and downy brome (Young and Evans 1971).

WEED-CONTROL SYSTEMS

The development of techniques has been described for controlling excessively dense stands of big sagebrush and releasing native perennial grasses. It has been stressed that sites without enough perennial grasses to preempt the environmental potential released by killing the brush should not be sprayed. If such degraded big sagebrush sites are not invaded by downy brome, the brush can be sprayed and a heavy-duty rangeland drill used to seed in the standing dead brush (Kay and Street 1961). For most sites, the use of a rangeland drill modified to make furrows

enhances seedling establishment (Asher and Eckert 1973).

For big sagebrush communities in which the perennial grasses are gone and downy brome has invaded the shrub understory, it is possible to combine in sequence 2,4-D and atrazine-fallow treatments into a weed-control system (Evans and Young 1977). The system can be used by (a) applying the atrazine in the fall and the 2,4-D the next spring, (b) applying the 2,4-D in the spring and the atrazine the next fall, or (c) applying a mixture of both herbicides in the spring at the optimum date for brush control.

Atrazine fallows make excellent seedbeds for transplanting seedlings of desirable browse species (Christensen and others 1974). Shrub transplanting can also be adapted to weed-control systems in which atrazine and 2,4-D are used (Evans and Young 1977).

MANAGEMENT

From the very beginning of research on control of big sagebrush, range scientists have stressed that probably more programs failed for lack of post-treatment management than for any other reason except the choice of sites with too few perennial grasses.

Ideally, areas treated with 2,4-D for control of big sagebrush should be allowed to rest the season after spraying and should not be grazed the next season until after the seeds of the perennial grasses are ripe. Subsequently, proper grazing management must be practiced to maintain the perennial grass stand. Such management requires fencing and water-source development. All too often the sprayed areas have been the only productive areas in grazing allotments, and the lack of post-treatment management has allowed overutilization of the perennial grasses that were released from competition when the brush was killed.

In degraded rangelands where big sagebrush is sprayed and perennial grasses are seeded or browse species are transplanted into the dead brush, grazing must be delayed for 1 to 3 years to protect the seedlings and young plants from damage until they become established.

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THE APPLICATION AND USE OF HERBICIDES FOR RANGE PLANT CONTROL

John F. Vallentine

ABSTRACT: Herbicides are an effective, necessary, and environmentally sound tool for the control of weeds and brush on rangelands. Failure to consider this alternative approach to plant control can seriously handicap or even prevent proper maintenance and improvement of rangelands. Selective plant control by mechanical, biological, fire, or manual means should also be considered but is not always a satisfactory alternative to chemical control. Any person who is involved or contemplates being involved in the development of rangelands must be well versed in the properties and proper use of herbicides.

INTRODUCTION

New herbicides, new formulations, new application techniques, and new uses for herbicides have been developed for rangelands in recent years. The effects of environmental factors on herbicidal effectiveness are now better understood, and safeguards have been developed for range and pasture application of herbicides with minimum risk of injury or damage to other portions of the environment. As a result, chemical control is probably the most widely used means of removing unwanted or noxious plants from range and other pasture lands.

Although the potential uses of herbicides on rangelands are much greater than indicated by this list, some of the proven benefits and uses are as follows:

1. Selective control of undesirable plants as a primary treatment while benefiting desirable forage species.
2. Combination treatment with mechanical, fire, or biological methods.
3. Maintenance control or retreatment when applied periodically following primary treatment.
4. Eradication of small infestations of serious plant pests, i.e. environmental contaminants not previously found locally.
5. Release of closed communities over which undesirable woody or even herbaceous plants have gained dominance.
6. Eradication of poisonous plants limited to sites suitable for such intensive treatment.
7. Thinning and removal of trash trees in commercial forests, thereby enhancing herbaceous and browse understory as well as timber production.
8. Destruction of phreatophytes and other water wasting plants.
9. Rejuvenation of tall shrubs and low trees for big game by top killing and stimulating new growth from sprouts and seedlings.
10. Total plant kill to meet the needs of chemical seedbed preparation for range seeding or planting.

Range managers who lack expertise in the use of herbicides should consider university credit courses, extension shortcourses, and self study of training materials. Handbooks and manuals suggested for planning and carrying out plant control programs on Intermountain rangelands, including the use of herbicides, include Bohmont (1981), Klingman and others (1982), Vallentine (1980), and Weed Science Society of America (1979). An expanded list of references on herbicide use can be found at the end of this article. Martinelli and others (1982) recommend all range managers take advantage of the program for training and certification of pesticide applicators. They conclude that these schools, now being offered in most states with EPA approval and financing, can be extremely valuable as a refresher program even if one does not plan to apply restricted herbicides. The opportunities for developing expertise in the use of herbicides are within reach of every range manager.

ADVANTAGES AND DISADVANTAGES OF HERBICIDE USE

Herbicidal control has distinct advantages over other plant control methods, and these explain the current widespread use of herbicides, particularly on private lands. These general advantages include:

1. Can be used where mechanical methods are impossible, such as on steep, rocky, or muddy sites or on many timbered sites.
2. Provides a selective means of killing sprouting plants that cannot be effectively killed by top removal only.
3. Provides a rapid control method from the standpoint of both plant response and acreage covered when broadcast applied.
4. Has low labor and fuel requirements.
5. Phenoxy herbicides are generally cheaper than mechanical control methods, but may cost more than prescribed burning.
6. Most herbicides are selective or can be selectively applied so that damage to desirable plant species can be minimized.
7. Maintains a grass and litter cover and does not expose soil to erosion.

John F. Vallentine is Professor of Range Science, Brigham Young University, Provo, Utah

8. Safe and reliable when proper safeguards are followed.
9. Can often utilize regular farm and ranch spray equipment.

Disadvantages of using chemicals to control undesirable range plants do exist, but recognizing them may permit minimizing or circumventing them:

1. No chemical control has yet proven effective or practical for some species.
2. Herbicides provide a desirable, non-competitive seedbed for artificial seeding only under certain situations.
3. Costs of control may outweigh expected benefits on low-potential range.
4. The careless use of chemicals can be hazardous to non-target plants in the stand, to cultivated crops or other non-target sites nearby, or may contaminate water supplies.
5. Lack of selectivity may result in killing associated forbs and shrubs important for grazing.

Greater selectivity can be realized with herbicides by carefully controlling the application rate, fully considering the relative growth stages of the target and non-target plant species, using appropriate or even differential application techniques, and using adequate but not excessive amounts of surfactants. Selective herbicides generally become non-selective when applied at excessive rates. Reduced susceptibility periods of desirable species in the plant composition can often be found and followed. For example, 2,4-D should be applied as early as good big sagebrush kill can be obtained in order to reduce damage to bitterbrush. Spraying at the time of leaf origin in bitterbrush, and before the appearance of distinct twig elongation or flowering, generally causes only slight damage to large bitterbrush plants. Selective application methods, as discussed later, permit non-selective herbicides to be used selectively.

Eradication, i.e. complete removal or kill, including reproduction potential, of undesirable range plants over large acreages is seldom feasible or even possible but may have local application. Areas treated with herbicides--and by most other control treatments as well--tend to become reinfested. This results from sprouting of the noxious woody and herbaceous species, by seedlings arising from seeds present in the soil or brought in accidentally, or by seedlings coming from plants missed in the initial treatment. Limiting the control level of brush species or spraying in narrow strips contribute to reinvasion and selective grazing patterns and should be avoided. When vegetation mosaics are desired, such as for wildlife, larger blocks of sprayed and unsprayed areas are suggested, with the lower potential sites being left unsprayed.

HERBICIDE APPLICATION METHODS

Several methods are available for applying herbicides to undesirable range plants. For convenience, these are divided into foliage application, stem application, and soil application:

- I. Foliage application
  - A. Spray
    - 1. Broadcast
      - a. Aerial (airplane or helicopter)
      - b. Ground
        - (1) Non-directional (boom sprayers and mist blowers)
        - (2) Directional
          - (a) In-row (rowed plants physically protected from spray)
          - (b) Strip (chemical seedbed preparation for interseeding)
  - B. Wipe-on (rope wicks, rollers, or sponge bars)
  - C. Dust (unimportant on range)
- II. Stem application (individual plant)
  - A. Trunk base spray (may be enhanced by use of frills or notches)
  - B. Trunk injection
  - C. Cut stump treatment
- III. Soil application
  - A. Broadcast (spray, granules, or pellets)
  - B. Grid ball (spaced placement of pellets)
  - C. Individual plant or motte
    - 1. Soil injection (liquid)
    - 2. Soil surface placement (around stem base or spread under canopy)

Broadcast spray application has been the most commonly used method on rangelands. Since the herbicide is applied to all plants on the site when broadcast, desirable as well as undesirable, selective herbicides are required. Broadcast spray applications can be made either by ground rigs or by aerial application. When herbicides are applied by ground rigs, a spray volume of 10 gal/acre (26.12 l/ha) is common but may vary from 5 to 40 gal (13.06 to 104.48 l/ha) depending upon need. With aerial application, spray volume can be reduced down to 1 to 3 gal/acre (2.61 to 7.83 l/ha), with ultra-low volumes down to 0.50 or even 0.25 gal/acre (1.31 to 0.65 l/ha) being satisfactory in some situations.

The comparative advantages of using broadcast ground application versus aerial application of herbicide sprays are as follows:

<u>Broadcast ground application</u>

1. Adapted to small acreages.
2. No landing strip required (pad only required for helicopter)
3. Less drifting and less subject to fog or wind.
4. Commercial equipment often not required.
5. Safer for applicators.

<u>Aerial application</u>

1. Faster coverage
2. Adapted to wet, rough, or rocky ground or

steep slopes.
3. Lower cost per acre on most large acreages.
4. No mechanical disturbance of soil or vegetation.
5. Better coverage of tall, dense brush or tree stands.

Although fixed-wing aircraft are more commonly used, helicopters are advantageous in some situations. Helicopters require no landing strip, are interfered with less by trees, snags, and steep terrain, permit slower airspeed for application, and have greater maneuverability. However, they are generally less available when needed, have reduced lifting power in thin, warm air, have reduced payload (50 to 150 gal [189 to 568 l] compared to 125 to 600 gal [473 to 2271 l]), and are more costly per acre on larger projects.

Foliage spray application with ground rigs generally utilize boom applicators that are as narrow as 4 ft (1.22 m) for hand application to as wide as 100 ft (30.48 m) for self propelled systems. However, boomless ground applicators have been used conveniently in tall brush, along fence rows, or in very rough terrain. Such mist blowers have also found use in applying low, defoliation levels of phenoxy herbicides using crosswinds of 5 to 12 mph (8.05 to 19.32 km/hr), thereby permitting strips up to 100 ft (30.48 meters) wide being covered. Wiper applicators have permitted taller, noxious plants being controlled with non-selective herbicides without damaging lowgrowing, desirable plants. Wiper applicators also have advantages in applying selective herbicides to herbaceous plants in that low volume is required, the amount of herbicide is reduced, spray drift is eliminated, and low cost equipment can be used.

Individual plant treatments including wetting sprays, stem application, or soil application may have advantages over broadcast application for spot infestations, for widely scattered plants, on terrain which is too rough for wheeled machinery, or where only a small portion of the plants are to be removed, such as in commercial forests. Individual plant treatment generally allows non-selective herbicides to to be used selectively through positive control of spray direction. However, individual plant treatments have a high cost per plant, high labor demand, slow job completion, and the difficulty of reaching plants over 6 feet high. Hand-held boom sprayers or mist blowers provide advantages somewhat intermediate between broadcast application and individual plant treatment.

Soil-active herbicides may be selective or non-selective and have either temporary or lasting effects. Herbicides such as dicamba, picloram, and triclopyr are effective when either soil- or foliage-applied. Atrazine, fenac, karbutilate, 2,3,6-TBA, and tebuthiuron are effective only when applied to the soil. Soil-active only herbicides are generally applied as dry granules or pellets since vegetation will intercept some or most of the spray, but other soil-active herbicides can be applied in either dry or liquid form.

Soil injection, soil surface placement around stem base, application in continuous narrow bands underground, or use of the grid-ball technique permit non-selective herbicides to be used with significantly reduced herbaceous plant injury. The gridball technique provides for placing pellets in grid fashion, resulting in columns of active herbicide in the soil that can intercept the deep roots of woody plants while minimizing intercept by the roots of herbaceous plants.

Applying soil-active herbicides in granular or pellet form has the advantages of minimizing drift; not being intercepted by foliage, controlled release; ease of handling and application; premixing, thereby reducing mixing errors; simple application equipment generally; and prolonged soil activity; where desired. Soil surface application is less dependent on stage of plant growth than foliage sprays but does require precipitation to dissolve and move the herbicide into the soil.

HERBICIDES FOR RANGE USE

The properties of herbicides used or proposed for use on rangelands are given in table 1. General information on clearance and general uses are included for each herbicide. The phenoxy herbicides including 2,4-D, 2,4,5-T, and 2,4,5-TP or silvex (and also MCPA and 2,4-DP or dichlorprop in some areas, or 2,4-DB when damage to legumes is to be avoided) have been the most widely used on rangelands. Herbicides such as glyphosate, karbutilate, tebuthiuron, and triclopyr are relatively new herbicides showing promise for special uses on rangelands. Other potential range herbicides in the experimental stage are fosamine, hexazinone, buthidazole, ethidimuron, prodiamine, and metribuzin. For specific herbicidal plant control recommendations, the reader is directed to selected entries in the reference section, particularly Alley and others 1978; Cords and Artz 1976; Heikes 1978; Higgins and others 1978; Jensen and others 1980; USDA 1980; and Vallentine 1980.

HERBICIDE APPLICATION EFFECTIVENESS

The right herbicide will only be effective when it has been formulated correctly, applied effectively and at recommended rates, and timed to meet the best plant growth stages and associated environmental conditions. The amount of herbicide required to provide adequate control varies with kind and form of herbicide, plant species, and method of application. Herbicide rate recommendations primarily consider optimum toxic effects within legal limits. Higher rates are rarely more effective and may prove detrimental. However, reducing rates below recommended levels

to save money or being environmentally super conscious may sharply reduce kills, particularly when less than ideal conditions are encountered. When multiple herbicides are required for additive or synergic effects or repeat applications are required for satisfactory kill, the single application of one herbicide but at a higher rate is seldom a satisfactory replacement.

Effective formulation of a spray mix involves mixing the selected toxicant (correct as to amount, concentration, and chemical and physical form) with the right kind and amount of carrier and adding in any additional surfactant needed. Water is the carrier most commonly used today, but the addition of diesel oil to comprise 20 to 25 percent of the total carrier may increase effectiveness with some woody plants. Water has good driving force through the upper foliage, is easier to work with, and is low cost; but the addition of diesel oil often reduces evaporation of the spray mix, spreads more evenly on the leaf, and penetrates plant cuticles better. Surfactants increase emulsifiability, spreading, sticking, and other desirable surface-modifying properties of the spray mix. They are added to the commercial product at the factory, but additional amounts or kinds may be included in specific recommendations. However, excessive use of surfactants may reduce or eliminate normal selectivity of a herbicide.

Proper swath widths are important in preventing skips or overlapping swaths and in obtaining complete coverage of the foliage in broadcast spray application. Since height above the ground will affect swath width, it should be carefully controlled. Application rates should be checked periodically by proper calibration methods and corrected as needed. Flagging is essential in aerial application, and some form of ground marking will generally be required with ground application. Many aircraft are now equipped with automatic flaggers which dispense strips of wet, colored paper to mark flight lines, therby reducing or elminating the need for manual flagging. Spray droplets should be large enough to minimize drift hazards and yet be sufficiently small and properly distributed to give good coverage.

The age, stage of growth, and rapidity of growth affect the susceptibility of plants to herbicides. The most effective kill by phenoxy herbicides and most other foliage-applied, translocated herbicides is obtained when carbohydrate production and translocation rate is at the maximum, often near full-leaf stage. Since such herbicides are carried with the photosynthate stream throughout the plant, intrinsic plant factors as well as external environmental factors that stimulate carbohydrate production and translocation generally increase plant kill. Maximum growth rate and thus herbicide kill are associated with ideal soil moisture and fertility, ideal temperature, and adequate light.

To get the best kill from broadcast spraying phenoxy herbicides, do not spray:

1. During prolonged drought when low soil moisture retards plant growth.
2. Before most leaves are well developed--exact timing will vary somewhat between different plant species.
3. After leaves have stopped growing rapidly, begin maturing, and develop thickened cuticles.
4. When plant growth has been retarded by late frost, hail, insects, or excessive leaf removal by grazing.
5. When temperature is over 90°F (32°C) or under 55°F (13°C). (Temperatures between 70° [21°C] and 85°F [29°C] are best.)
6. When wind is above 10 mph (16 km/hr) for aerial application or 15 mph (24 km/hr) for ground spraying, or the air movement is being subjected to great turbulence and up-drafts.
7. When thunderstorms are approaching. (Rain 4 or 5 hours after spraying will reduce effects very little.)

REGISTRATION OF HERBICIDES

The Pesticides Registration Division of the U.S. Environmental Protection Agency is charged by federal law with approving all pesticide uses, regulating instructions on pesticide lables, and maintaining environmental and health standards associated with pesticide use. It also sets tolerance levels in animal feeds and human foods, can seize any raw agricultural commodities not complying with these tolerances, and punish violators using nonregistered pesticides or making unapproved use of registered herbicides. Tolerance levels include rather large safety factors and are commonly set at one percent or less of the highest level causing no adverse effect in the most sensitive animal species; but zero tolerance is mandatory in some cases.

In addition to the EPA, one lead agency within each state is designated by its governor to participate in pesticide regulation within that state. Individual states may have special registration and use requirements for pesticides. Also, the designated state agency is charged with certifying pesticide applicators. Only certified pesticide applicators are permitted to purchase or use restricted use pesticides, including paraquat and picloram or those on emergency exemption.

EPA Compendium of Registered Pesticides, Volume I (1974 plus updates) is the official source of new uses and changes in old uses of federally registered herbicides. Basic information is provided about each chemical, including the information on the herbicide label. Sample specimen labels can also be obtained from herbicide manufacturers. In addition to the regular federal registration of pesticide uses, three special registrations are provided for additional pesticide use approval:

1. Experimental label. This special federal label permits new products or old products being considered for new uses being researched and

evaluated before final approval.
2. Emergency exemption. EPA may exempt any federal or state agency so requesting unapproved pesticide usage provided that the emergency requires such exemption.
3. Special state label. A state may provide registration for additional uses of federally registered pesticides within the state, if such uses have not previously been denied, disapproved, or cancelled by EPA. However, EPA must give final approval.

HERBICIDE SAFETY PRECAUTIONS

Herbicides now approved for range and pasture use pose no hazard to livestock, wildlife, the applicator, or local inhabitants when properly applied. However, livestock should be prevented access to spraying equipment, herbicide containers, or herbicide in concentrated form. Phenoxy herbicides temporarily increase the palatability of affected plants, and this may increase the hazard from poisonous plants. In some cases the natural poisoning agent in the poisonous plants may be increased also. For these reasons, care must be taken that poisonous plants are not grazed until they begin to dry and lose their palatability (generally three weeks or more after herbicide application).

Even though herbicides are among the least hazardous of all pesticides, recommended safeguards in their handling and application must be followed. These routine safeguards include following all directions and restrictions shown on the pesticide label, storing pesticides only in the original containers, disposing of excess chemicals properly, and cleaning spraying equipment after use.

Herbicide drift is a special problem associated with foliage spray applications, and can be hazardous to susceptible plants down wind unless controlled. The direction, distance, and amount of spray drift that result before the herbicide reaches the ground are influenced by several factors. These include the size of droplets, their specific gravity, evaporation rate, height of release, direction and velocity of the wind, vertical air movements, and type of application equipment used. Spray drift is a greater problem in aerial application because of elevated release point and air turbulence generated, but can be serious in ground application as well. Herbicides that volatize after application are subject to wind movement a second time. Certain ester forms of the phenoxy herbicides are highly volatile while others are not. Low volatile ester or salt forms should be selected for use if susceptible crops or areas to be protected are in the immediate vicinity.

In addition to using herbicide formulations with low volatility and thus drift potential, other means of reducing drift of herbicides include:
1. Use application equipment that maintain adequate size and uniformity of droplets. Finely atomized spray drops may drift from the target area or evaporate before reaching the foliage.
2. Reduce height of release, particularly in aerial application.
3. Avoid spraying on windy days and when vertical air movement is great--favorable conditions are more apt to be found in early morning, late evening, and night.
4. Use water as the carrier since water droplets are heavier and drift less than oil droplets; but anti-evaporants may be needed to reduce evaporation in dry atmospheres.
5. Select spray days with a slight, continuous wind movement blowing away from susceptible crops.
6. Use positive liquid shutoff systems in aerial application and avoid making flights over susceptible crops.
7. Use invert emulsions (water in oil); however, special equipment will be required to apply because of thick, non-flowing physical characteristics.
8. Use granular formulations of soil-active herbicides.

Table 1. Properties of herbicides used on rangeland or proposed for range use.

Common Name (Trade name)	Group and type of herbicide	Uses and restrictions[1]	Range and pasture uses; comments
Amitrole (Amino-triazole and Weedazol)	Triazole; foliage, nonselective, translocated.	Noncropland use principally.	Used on Canada thistle, horsetail, leafy spurge, whitetop, cattails, poison ivy. Persists 2-4 weeks in soil.
Atrazine (AAtrax)	Triazine; selecttive, soil sterilant.	Noncropland use; experimental on range.	Kills annual grasses and shows promise for chemical fallow on range. Persists for over 1 year in soil. Has increased protein content in perennial grasses.
Dalapon (Dowpon and Baspafon B)	Alaphatic; translocated, selective, foliage.	Pasture or noncropland use.	Foliage spray on emerged aquatics such as cattails and rushes, also medusahead and foxtail barley. Nonvolatile. Persists in soil up to 2-6 weeks.
Dicamba (Banvel)	Benzoic; selective, translocated, foliage or soil	Cleared for pasture and range at rates up to 8 lb a.i./acre (9 kg/ha)	Controls difficult plants such as Russian knapweed, Canada thistle, leafy spurge. Also useful in brush control. Persists in soil for up to a few months. Nonvolatile.
2,4-D (several trade names)	Phenoxy; selective, translocated, foliage.	Pasture and range.	Highly effective as foliage spray on many broadleaved herbaceous plants and some shrubs. 2,4-D amine used in frill cuts. Persists in soil for 1-4 weeks. Volatility depends on chemical form.
Fenac (Fenac)	Phenylacetic; translocated by roots, selective, temporary soil sterilant.	Spot treatment on range.	Used on Canada thistle, leafy spurge, Russian knapweed, and woody plants. Persists one year or longer in soil.

[1] Registration of herbicides for range and pasture uses and the accompanying restrictions are subject to continual change. Current clearance and restrictions at both state and federal levels should be checked and complied with.

Table 1. (con.)

Glyphosate (Roundup)	Alaphatic; non-selective, translocated, foliage.	Mostly experimental on range; broad spectrum herbicide.	Shows promise in brush control but also kills desirable grasses and forbs. Shows promise in killing undesirable grasses such as foxtail barley or saltgrass. Persists 1-3 weeks in soil.
Karbutilate (Tandex)	Carbamate and substituted urea; non-selective, soil applied.	Experimental on range; noncrop herbicide.	Effective on many plant species; injurious to forage plants; persists several months in soil.
Paraquat (Ortho Paraquat)	Bipyridyl; selective to non-selective, contact, foliage.	Use as spot treatment on noncropland or pasture or range renovation.	Major interest in grass seedbed preparation by application at .25-1 lb/acre (0.28-1.12 kg/ha) just prior to seeding. Rapid acting, nonvolatile. Soil contact inactivates. Has minor effect on broadleaf perennials. Low rate (0.2 lb/acre [.22 kg/ha] chemically cures but does not kill perennial grasses.
Picloram (Tordon)	Picolinic; selective, translocated, foliage or soil.	Noncropland, spot treatment. Limited clearance in some states for range use.	Effective on leafy spurge, Russian knapweed, low and tall larkspur, whorled milkweed, and also many shrubs such as rabbitbrush and oaks. Nonvolatile. Rates over 1 lb./A (1.12 kg./hectare) may persist for 2 or 3 years. Often synergic with phenoxy herbicides.
Silvex or 2,4,5-TP (Kuron, Weedone)	Phenoxy; selective, translocated, foliage.	Pasture and range clearance. Do not use on newly seeded pasture or range.	Plant control including oaks, maples, yucca, cholla, pricklypear, tall larkspur, saltcedar, and Dalmation toadflax. Persists 2-5 weeks in soil. Also for basal stem or stump treatment.
2,4,5-T (several)	Phenoxy; selective, translocated, foliage.	Rangeland clearance.	Foliage spray on woody plants including oak, maple, mesquite, elm, ceanothus, cholla, roses, huisache, pricklypear, and yucca. Also used in basal trunk spray, frills, and stump treatment; persists 4-8 weeks in soil.
2,3,6-TBA (Benzac, Trysben)	Benzoic; nonselective, soil sterilant.	Noncropland or spot treatment on range. Not for food or feed crops.	Used on leafy spurge, Canada thistle, Russian knapweed. At high rates persists 18-24 months.
Tebuthiuron (Spike, Graslan)	Substituted urea; nonselective, translocated, soil sterilant.	Experimental on rangelands; cleared for range use in some states.	Holds promise for controlling woody plants. Persists up to several months. Spot apply or broadcast as pellets.
Triclopyr (Garlon)	Phenoxy-picolinic; selective, translocated, foliage or soil applied.	Experimental on rangelands.	Shows promise on broadleaf weeds and shrubs including oaks and other root sprouters. Also effective in basal spray and trunk injection. Degraded rapidly in soil.

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MECHANICAL CONTROL OF SAGEBRUSH

William F. Davis

ABSTRACT: The success of sagebrush (Artemisia spp.) control must be measured according to the objective to be obtained. Where seeding other species for forage and longevity is an objective, then a high degree of initial control of existing sagebrush plants is necessary.

INTRODUCTION

Before selecting a method or combination of methods to be used for mechanical control of woody species of sagebrush (Artemisia spp.), one should first identify the habitat types or sagebrush subspecies to be treated. This information provides insight into the site potential for herbage production (McDonough and Harniss 1975). It also aids in selecting species for seeding and defining realistic objectives to be accomplished by the control effort (Hironaka and others 1983).

Methodology is too often selected because of initial cost or equipment availability. Ideally, one should identify the results desired based on well-developed objectives and then select the most appropriate methodology. Economics is an important factor to be considered in selecting a method for sagebrush control. Frequently, only the investment cost of the initial treatment is considered. Inadequate attention is often given to the quality of seedbed preparation, the timing of seeding, the degree of control of competitive species, the short- and long-term benefits to be obtained, and necessary follow up treatments (Frischknecht and Bleak 1957; Nielsen and Hinckley 1975).

Many variables influence the success of initial sagebrush control and the reinvasion of shrubs into the treated area. The greatest economic return for livestock results from methods that require the shortest periods of nonuse and yield at least 15 years of relatively uniform production (Pechanec and others 1954).

Some sagebrush eventually reinvades most treated sites. The rate of return is primarily related to the effectiveness of the initial control (Welden and others 1958) and the success of the seeding (Robertson and others 1966). Shrub reestablishment has been reported to occur in wet years (Frischknecht and Harris 1968) and is hastened by heavy grazing (Johnson 1969). However, Bartolome and Heady (1978) found no significant correlation between shrub reestablishment and amounts of moisture received on grazed ranges, but reported that sagebrush invades rapidly after treatment and may continue to increase for several years thereafter. Frischknecht and Harris (1968) reported that in some years reinvasion occurred even without grazing.

Hull and Klump (1966) described treatments consisting of sagebrush removal followed by crested wheatgrass (Agropyron desertorum or Agropyron cristatum) seedings at nine locations in southern Idaho. These seedings were all below 5,800 ft (1 768 m) elevation on abandoned farmland, plowed or fallowed land, or recently burned areas. The authors assumed that little sagebrush escaped removal from the sites prior to seeding. They found that many of the 30-year-old seedings were still productive and most showed no sign of deterioration after more than 20 years of rotation grazing at about 3 acres (1.2 ha) per animal unit month. However, they also recommended a maintenance sagebrush control at some locations every 10 to 20 years. Such recent observations at these and similar sites indicate that plantings on the most productive sites tend to be reoccupied by sagebrush sooner than plantings on drier sites, and that mountain big sagebrush and basin big sagebrush are more aggressive than Wyoming big sagebrush (U.S. Department of Agriculture, Forest Service[1]).

Blaisdell (1949) pointed out that sagebrush plants that survive brush control treatment have a distinct advantage over seedlings of planted grasses. However, sagebrush seedlings that became established at the same time as the grasses did not always display an initial advantage. Plummer and others (1955) stressed elimination of competing species by comparing sections of a 2-year-old crested wheatgrass seeding. The seeded grasses produced 1,785 lb (809 kg) of air-dry grass per acre in areas where 92 percent sagebrush control occurred, and 529 lb (240 kg) of air-dry grass in areas with 53 percent sagebrush control.

Bartolome and Heady (1978) conclude that the reinvasion of sagebrush on treated sites in Oregon was due to the recovery of plants that had not been killed and the growth of seedlings established during the first few years following treatment. Shrubs that established in later years usually remained small and did not mature. Sagebrush reinvasion did not result in deterioration of the perennial grass stand or in a reduction in grass production.

William F. Davis is Range Improvement Specialist for the Intermountain Region, USDA Forest Service, Ogden, Utah.

[1]U.S. Department of Agriculture, Forest Service. Ogden, UT: Data on file at U.S. Department of Agriculture, Forest Service, Intermountain Region, 1960-1983.

Efforts to control sagebrush have had a long and interesting history. Burning and mechanical techniques were essentially the only methods available until herbicides came into use following World War II. Increased interest in seeding or otherwise improving depleted ranges following the war led to the 1946 organization of the Range Seeding Equipment Committee, now the Vegetative Rehabilitation and Equipment Workshop (VREW), which has devoted a great deal of time and effort to the testing and development of suitable equipment for range improvement (Larson 1982).

MECHANICAL EQUIPMENT FOR SAGEBRUSH CONTROL

Root Plows

Several early attempts were made to design and construct root plows to treat woody species. These plows worked reasonably well on moderate to deep soils that were free of rocks, but power requirements were high compared to plow width and digging depths. Large root plows provided acceptable kill of root sprouting shrubs in the southwest (Gonzalez and Dodd 1979). Although they have been successful for controlling sagebrush in the Intermountain area, they also destroy desirable herbs and shrubs. The blades are drawn laterally through the soil, cutting and uprooting all species. Soil moisture levels, percent of rock, and density of vegetation determine the power requirements and production rates. Under normal conditions, 1 to 4 acres (0.4 to 1.6 ha) can be treated per hour (Larson 1980).

Brush Rake

Various types of rakes have been tried but none have proven successful for elimination of sagebrush. Older woody brush can be removed, but younger, more flexible plants remain. Most rakes were not built to treat low growing shrubs, consequently their use on rangelands is quite limited (U.S. Department of Agriculture, U.S. Department of the Interior, Range Seeding Equipment Committee 1957).

Dixie or Pipe Harrow

The pipe harrow got its beginning on the Dixie National Forest in Utah. Spikes were driven into green poles that were attached parallel to each other and pulled lengthwise by a team of horses. Some success was obtained, and soon the steel harrow appeared (Plummer and others 1955). Self-cleaning pipe harrows are well adapted to rocky and rough ground. They are most effective for covering broadcast seed or burns in areas where trees or rocks prevent the use of larger equipment. They are only moderately effective in controlling brittle sagebrush plants. Twice-over treatment of brittle brush has been reported to control 70 percent of the brush, although this is believed to be the exception rather than the rule (U.S. Department of Agriculture, U.S. Department of the Interior, Range Seeding Equipment Committee 1957). Depending on the terrain and shrub density, up to 3.4 acres (1.4 ha) per hour can be treated using a 14-ft (4.3-m) wide harrow drawn by a 50-hp (67.0-kW) (drawbar) tractor (U.S. Department of Agriculture, U.S. Department of the Interior, Range Seeding Equipment Committee 1965).

Rail Drags

Rail drags appeared in many configurations and were probably the first successful implements used to control shrubs. Designs of importance are essentially either single bars or a series of bars pulled in tandem. The bottom of the rail is the cutting edge and slides along next to the soil. To provide a cleaning effect, most drags are either built in sections or in an open V or A configuration (U.S. Department of Agriculture, U.S. Department of the Interior, Range Seeding Committee 1957).

Satisfactory kill of sagebrush is seldom obtained unless the shrubs are over 2 ft (0.6 m) tall and old enough to be brittle. Because young plants usually are not affected by the treatment, only 30 to 80 percent of most stands are killed. Large rocks and cold weather contribute to substantial equipment damage (Pechanec and others 1954). Power requirements are relatively high, 40 to 60 hp (31 to 45 kW) for a 16.5-ft (5.0-m) A-rail unit width. The "supp rail" and the "rail drag" designs require less power (Larson 1980).

Light-weight rails were often used to mash tall brush down, forming a continuous fuel supply prior to prescribed burning and seeding. Sagebrush kills of up to 99 percent have been attained using this combination of techniques (U.S. Department of Agriculture, Forest Service, see footnote 1).

Brush Beating

Brush beaters employ a series of hammers or flails attached to a horizontal shaft that is rotated at high speed using the power take-off from a tractor. Some units are powered hydraulically or by separate engines. Once-over beating seldom provides good kill of large sagebrush; twice-over beating is usually required to reduce the large stems to litter. Large rocks and woody stems over 3 inches (7.6 cm) in diameter damage the beater (Plummer and others 1955). Short or flexible brush normally cannot be controlled by beating.

Brush beaters have not proven adequate for control of brush on Forest Service projects. Power requirements are high in relation to acreage covered, although 20-hp (14.9-kW) tractors have successfully powered small units (U.S. Department of Agriculture, U.S. Department of the Interior, Range Seeding Equipment Committee 1965). Power requirements increase with height and density of brush. Brush stands generally recover in less than 5 years unless

additional measures such as fire or herbicides are employed. Beating causes little soil disturbance or damage to understory species and is best completed during early growth periods for 2 consecutive years.

Rotary Mower

In contrast to the brush beater, the rotary mower consists of rotating knives attached to vertical shafts. Power is usually supplied by the power take-off. Once-over mowing does a complete job of reducing vegetative material to litter. Good kill of large, nonsprouting shrubs such as sagebrush is obtained, but seedlings and young plants are not always damaged. Like the beaters, the usefulness of rotary mowers is limited in rocky areas. Power requirements are higher than for beaters, but twice-over mowing is seldom needed (Larson 1980).

Rotary mowing 1 year prior to using herbicides proved to be an effective treatment on the Bridger-Teton National Forest, Wyoming, where esthetic considerations were critical. Costs for 1982 were estimated at $10 per acre ($25/ha) on abandoned farmland and other rock free terrain (U.S. Department of Agriculture, Forest Service, see footnote 1). Use of the rotary mower cannot be termed successful for sagebrush control on a long-term basis. However, depending on the objective, it may be considered a useful tool when control is required for less than 5 years.

Moldboard Plow

Plowing is probably the most effective mechanical method for maximum control of sagebrush as well as control of most other competing species. The moldboard plow can be used to good advantage on relatively level, rock-free soil. Because of its relatively high power requirement and slowness, the moldboard plow is more expensive to use than are disk-type plows. The moldboard plow requires approximately 20 hp (15kW) (drawbar) to plow a 42-inch (1.1-m) swath (Larson 1980).

Wheatland Plow

The wheatland plow is well adapted to relatively level sagebrush areas. It cannot be used on rocky sites without a high risk of damage. Nonsprouting sagebrush can be controlled when plowed at 2- to 4-inch (5- to 10-cm) depths. When sprouting plant species are to be controlled, plowing at 4- to 6-inch (10- to 15-cm) depths is needed. Even better results can be obtained by dragging sections of spiketooth harrows in tandem behind the plow. Harrowing is well worth the added cost in most cases. The second section of the harrow should be chained directly to the front section using a 2-ft (0.6-m) spacing. This arrangement allows the two sections to work independently and deposit root sections on the soil surface to dry in the sun.

Where control of cheatgrass (Bromus tectorum), bulbous bluegrass (Poa bulbosa), and similar herbaceous plants, as well as sagebrush and sprouting shrubs, are part of the objective, shallow plowing and harrowing early in the growing season and again during mid-season will provide good results. This adaptation can also be applied to other types of disk plows. Double plowing and harrowing with a properly adjusted wheatland plow should consistently provide over 90 percent control of all sagebrush (U.S. Department of Agriculture, Forest Service, see footnote 1).

Tandem Disk Plow

The offset disk plow is a tandem disk with the front section disks facing one way and the rear section disks facing the opposite direction. This arrangement double plows the area with the rear disks tracking in a line between the front disks. Frames may either be ridged or sectioned depending on the design. As with other disk plows, disks should be 24 to 28 inches (61 to 71 cm) in diameter to provide adequate tillage depth and clearance when used on rangeland.

Tandem disk plows obtain about the same degree of sagebrush control as the wheatland plow. Due to their heavy weight, they offer an advantage over the wheatland plow in heavy, tight soils, and on rough terrain. Tandem plows also have a distinct advantage over the wheatland plow where large amounts of herbaceous vegetation must be controlled. The heavy machine cuts and underturns the vegetation into the soil. Where double plowing is needed, the lighter weight wheatland plow has the advantage. A second plowing, later in the growing season, further reduced competitive plants resulting in better control of vegetation.

Tandem disk plows are easy to adjust and perform well over changing soil conditions. However, operators tend to allow these plows to work deeper than necessary, thus wasting power and time. Plummer and others (1955) recommended plowing to depths of 5 to 7 inches (13 to 18 cm) when controlling sprouting species such as rubber rabbitbrush (Chrysothamnus nauseosus). The Ashley National Forest has obtained good results by deep plowing using the Amco plow and spike tooth harrow combinations in removing a tall-dense stand of rubber rabbitbrush on deep mudstone shale deposits.

Brushland Plow

Due to the inability of the first wheatland plows, and most disk plows, to withstand work on most National Forest rangelands, the need for a more sturdy machine was soon recognized. Wheatland plows and disk plows built prior to the mid-1940's were not designed to handle rocky soils and heavy stands of brush. Frames and assemblies were almost ridged, lacked adequate clearance, and could not withstand the hidden rock outcrops and stumps.

The brushland plow was designed from an Australian "stump-jump plow" by the San Dimas Equipment Development Center. The plow consists of seven pairs of disks independently mounted on spring-loaded arms. This implement is useful for controlling shrubs on rough, rocky terrain (Larson 1980). Brushland plows as we know them today can be used in pairs and are reported to be more efficient in power requirements than wheatland plows of similar cutting widths. The heart of the brushland plow is the independent spring-loaded disk assemblies consisting of two disks. The front disk is 28 inches (71 cm) and the rear disk 24 inches (61 cm) in diameter. The two disks bolt solidly to a single axle mounted at an angle to the forward motion to allow the disks to scoop as they roll. Due to the difference in diameters, the rolling disks set up a slicing action that aids in cutting through plant material instead of rolling over it (Larson 1980).

The brushland plow weighs nearly 3.5 tons (3.2 metric tons), nearly double the weight of a wheatland plow of similar working width, yet less drawbar power is required to pull it. Control of sagebrush showed the brushland plow to provide about 90 percent control compared to wheatland and offset disk plows, which each gave about 75 percent control on the same site (Plummer and others 1955). Spike-tooth harrows attached to the brushland plow would be a worthwhile addition for control of sprouting species.

Anchor Chains

Three basic chains are available for use on sagebrush sites. The slick or unmodified chain is sometimes used but is largely ineffective unless individual links weigh 90 lb (41 kg) or more and sagebrush is large and brittle. Young or flexible plants are not effectively removed. Because of the difficulty of controlling brush, most chains have been modified into two basic designs.

Chambers (1967) described a chain modification generally known as the Ely Chain. Steel rods approximately 18 inches (46 cm) long are welded across each chain link so that approximately 4-inch (10-cm) projections are at right angles to the link. Links of about 40 to 60 lb (18 to 27 kg) each with about 30 lb (14 kg) of light railroad rail are generally used. On some chains, old truck axles have been used and even new cold rolled steel. Ideally, the base would be cut from railroad rails in order to remove the potential for brush to catch and wrap around the chain. Tips of the projections should be hard surfaced with welding rods, such as Marquette No. 455. Marquette No. 7018 rod, 3/16-inch (0.47-cm) diameter, can be used to weld cross pieces to chain links.

Jensen (1969) described another chain modification known as the Dixie Sager. This chain used in combination with the Ely Chain provides more effective control of sagebrush than either chain used alone. The Dixie Sager is more difficult to manufacture than the Ely Chain because the rails are welded lengthwise to the rounded chain link, requiring about twice as much welding. Before attempting to weld on a surplus anchor chain, it should be used for chaining for a few hours to polish the link and remove all forms of corrosion. Rail sections should have the bottom flange completely removed, leaving the top of the rail to be welded to the link and the center part of the rail as a projection. The rail section should only be long enough that it can be solidly welded to the link, leaving nothing to catch and hold brush. All wear points should be hard surfaced to maintain approximately 4 inches (10 cm) projecting as a scarifier. The chain must be self cleaning and be kept reasonably free of brush to provide satisfactory brush control.

After numerous chainings on several National Forests in Utah, we have concluded that it is best to use two 150- to 200-hp (112- to 149-kW) crawler tractors. Approximately 45 ft (14 m) of medium-weight smooth chain with 1.5-inch (3.8-cm) diameter links is hooked to each tractor. To the ends of each smooth chain is attached a specially constructed swivel made from rebuilt track rollers from D-9 Caterpillar tractors. These heavy swivels remain close to the soil surface and are each attached to a 60-ft (18.3-m) section of Dixie Sager. The remaining ends of the Sager chains are attached to the ends of a 40-link section of Ely Chain (U.S. Department of Agriculture, Forest Service, see footnote 1).

The two tractors attempt to operate nearly parallel to each other, pulling the 225 to 250 ft (69 to 76 m) of chain in an open V or U shape. The modified portions of chain slowly turn with a self-cleaning sawlike action as they slide over the soil surface. Swivels must be greased at least once each day. Maximum scarification and brush removal is obtained with the tractors operating close together. Scarification is greatly reduced if tractors operate more than 75 ft (23 m) apart. This maximum spacing should be specified in all contracts and strictly enforced. As a rule of thumb, the total chain length should exceed three times the spacing of the tractors as measured from drawbar pin to drawbar pin. The Dixie Sager does not work well in the center of the chain because it is more prone to roll than is the Ely chain. Only moderate sage control can be expected along the center of the chain, but nearly 90 percent control can be obtained along the two outer one-third sections of the swath, providing the chain is kept reasonably clean and the tractors do not exceed the optimum spacing of 75 ft (U.S. Department of Agriculture, Forest Service, see footnote 1).

As with other mechanical methods of sagebrush control, chaining is most effective on older, brittle plants and least effective on young or flexible plants. The anchor chain is probably the least understood tool commonly used for control of sagebrush and juniper (*Juniperus* spp.). The difference between obtaining a good kill of target plants and project failures is often the result of one or more of the following

considerations: (1) objectives of the project, (2) project supervision, (3) tractor spacing, (4) chain design, or (5) chain repair and maintenance.

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TREATMENT OF INLAND SALTGRASS AND GREASEWOOD SITES TO IMPROVE FORAGE PRODUCTION

Bruce A. Roundy, Greg J. Cluff, James A. Young, and R. A. Evans

ABSTRACT: Greasewood and saltgrass sites that once supported basin wildrye can be highly productive after chemical brush control and forage restoration by proper management or by seeding. Application of 2,4-D in June, once or for 2 consecutive years, effectively controls greasewood and salt rabbitbrush. Associated saline soils can be successfully seeded to salt-tolerant grasses such as basin wildrye and tall wheatgrass by using irrigation or on sites where salinity is low and in years when spring precipitation is high.

SITE DESCRIPTION AND POTENTIAL

The decisions of how to manage or treat a specific site to increase forage production are most dependent upon the site potential and associated limiting factors to plant establishment and growth. A brief discussion of the ecological setting of greasewood and saltgrass sites will aid in understanding the potential of these sites. Basin and range faulting began in the Miocene in the Great Basin and created many closed basins (Papke 1976). During the Pleistocene, reoccurring periods of cold, moist climatic conditions resulted in the creation of two large pluvial lakes, Lake Lahontan in Nevada and Lake Bonneville in Utah, and numerous smaller lakes in many different basins (Morrison 1964; Papke 1976). The variable level of these Pleistocene lakes over the years resulted in a series of terraces superimposed on the alluvial fans of the adjacent mountains (Hunt 1967).

As the climate became more arid, most of these lakes evaporated completely leaving salts and fine sediments in the lake beds which are now known as playas (Papke 1976). Since the lakes became more saline as they shrunk, concentric zones of increasing salinity occur from the upper terraces to the valley bottoms (Flowers and Evans 1966). Further salinization of these basins and salinization of other basins and floodplains which never had a pluvial lake has occurred due to restricted drainage. As salt-bearing waters drain from upland areas, ground water may be raised to the soil surface of lower lands. Subsequent evaporation of moisture on the soil surface results in the accumulation of salts which are not leached out due to low precipitation and drainage (Richards 1954).

Greasewood and saltgrass dominated plant communities generally occur in these lowland floodplains and basins below the upper and higher precipitation sagebrush zone that Billings (1945) considered edaphic climates within the drier shadscale zone. These sites are characterized by low precipitation of 5 to 10 inches (12 to 25 cm) annually, saline and fine textured soils, a shallow water table and in some areas, seasonal flooding. Plant growth and distribution are affected by total soil salinity, concentrations of specific ions, and depth of soil salts, soil aeration, and depth of the watertable and salinity of ground water, total soil water potential as affected by salts (soil osmotic potential) and water content (soil matric potential) and the seasonal variability of these factors.

Great variability in these factors may occur over short distances due to location of beach ridges, drainages, and springs and may result in highly variable plant communities and site potentials. In these soils Na, Cl, and SO_4 are the major ions (Kelly 1951) and Ca and Mg are minor. B concentrations may also be high. Excessive Na concentrations result in poor aerations, slow infiltration and slow permeability of these soils (Naphan 1966).

Despite all these limiting factors, range improvements are of interest because these ranges are extensive and convenient to many ranch base properties and because some sites historically produced tremendous amounts of forage before they were misused. The subsurface and overland drainage water these areas receive may help highest condition basin wildrye stands produce up to 7,136 lb/acre (8000 kg/ha) (Lesperance and others 1978) and the wettest and most dense saltgrass meadows produce 2,319 lb/acre (2600 kg/ha). More commonly, good condition wildrye and saltgrass stands could be expected to produce about 892 lb/acre (1000 kg/ha).[1] Winter and fall grazing of standing wildrye would protect this grass which is sensitive to spring-grazing, and save ranchers tons of alfalfa hay. Saltgrass is resistant to heavy grazing and its meadows stay green into the summer after upland bunchgrasses have gone dormant.

Although greasewood is estimated to cover 12.6 million acres (5.1 million ha) (USDA 1936), the site potential and associated species may vary greatly. Both greasewood and saltgrass occur over wide ranges in soil moisture, salinity and drainage. The plants they are associated with

Bruce A. Roundy, James A. Young and R. A. Evans are Range Scientists at the Renewable Resource Center, USDA Agricultural Research Service, Reno, Nev. Greg J. Cluff is a Range Agronomist at the University of Nevada, Reno.

[1] Roundy, B. A. and G. J. Cluff, Reno, NV: Data on file with USDA/ARS; 1977-1980.

may be more indicative of limiting factors and site potential. Many descriptive and some quantitative studies have been conducted in the basins of the arid west, some of which had the intent of using plant species to indicate soil conditions (Kearney and others 1914; Shantz and Piemeisel 1924, 1940; Flowers 1934; Billings 1945; Gates and others 1956). In table 1 some of the most common associates of greasewood and saltgrass are listed with plant tolerances and site conditions with which they are generally associated as summarized from the literature and our own experience at the Gund Research and Demonstration Ranch in central Nevada (see Young and Evans 1980).

Soil salinity, soil moisture and understory cover should be considered in deciding on brush control and seeding treatments to improve forage. Sites that have little understory and are too dry or too saline to seed should be avoided. Greasewood/shadscale and greasewood/kochia areas generally fall into this category. Sites where greasewood and saltgrass are associated with white-flowered rabbitbrush, pickleweed, salicornia, alkali grass or nitrophila generally have soils of high salinity and a high watertable. Only where a good grass understory already exists should these communities be treated to control brush. Sites that should be considered for brush control are those that have a good understory of basin wildrye, saltgrass, alkali sacaton or other forage grasses or that may be lacking in understory but have soils of low to moderate salinity. Greasewood and saltgrass in these situations are generally associated with big sagebrush and/or salt rabbitbrush.

BRUSH CONTROL

The effects of rotobeating and soil and foliar applied herbicides on control of big sagebrush, salt rabbitbrush, white-flowered rabbitbrush and greasewood were studied over a 6 year period in central Nevada. The foliar herbicide trials were conducted on small plots using a back-pack sprayer and on large plots using a rangeland ground sprayer (Young and others 1979). Trials were conducted on the following brush communities: Greasewood/salt rabbitbrush, greasewood/salt rabbitbrush/ white-flowered rabbitbrush and big sagebrush/salt rabbitbrush/greasewood. These communities occur on the lake plain of now-dried Pleistocene Lake Gilbert above the playa in the valley bottom and below the big sagebrush-dominated alluvial fans of the Simpson Park Mountains. The saline soils and drainage patterns of this lake plain are typical of many other areas in the Great Basin dominated by greasewood (Young and Evans 1980).

Rotobeating these communities resulted in less than 15 percent mortality each of greasewood, salt rabbitbrush and white-flowered rabbitbrush since these shrubs resprout. Rotobeating of big sagebrush/greasewood/rabbitbrush communities may kill the mature sagebrush and result in complete dominance by greasewood and rabbitbrush.

Control of greasewood and rabbitbrush by soil-applied herbicides including karbutilate (tandex), tebuthuiron (spike), buthidazole (ravage) and picloram was generally unsuccessful possibly due to the low permeability of the associated saline-sodic soils. Highest mortality was only 40 percent from 10 percent picloram pellets while other herbicides averaged less than 30 percent mortality.

A variety of foliar-applied herbicides including 2,4-D plus picloram, triclopyr, 2,4,5-T, silvex and dicamba were more successful than soil herbicides in controlling rabbitbrush and greasewood (Cluff and others 1983). None of these herbicides were more effective than 2,4-D applied during the period of optimum susceptibility. Mortality from foliar herbicides varied among years and sites and was correlated with soil moisture potential and greasewood and rabbitbrush growth phenology (Cluff and others 1983). Rabbitbrush grows slowly from March until late May when it begins a period of rapid growth that generally ends in early August (Roundy and others 1981, fig. 1). Greasewood generally begins rapid growth similar to rabbitbrush in late May, but has a lower rate and shorter period of rapid growth that generally ends in late June. Greasewood and salt rabbitbrush were most susceptible to 1.9 lb/acre (2.2 kg/ha) 2,4-D applied during mid-June when both shrubs were rapidly growing with mortality averaging 72 and 87 percent, respectively. An average leader length of 1.6 inches (4 cm) indicates that rapid growth of salt rabbitbrush is under way while the first opening of flower buds is correlated with rapid growth cessation (Roundy and others 1981). Appearance of staminate spikes is correlated with beginning of greasewood rapid growth and the appearance of dried spikes indicates rapid growth has ceased.

On a xeric site dominate by big sagebrush, greasewood and salt rabbitbrush, sagebrush was most susceptible to 2,4-D in mid-May while greasewood and rabbitbrush were more susceptible in June (table 2). On this xeric site, greasewood had a much lower growth rate and much lower mortality (table 2) than greasewood on a mesic site. Greasewood that has been sprayed and resprouts the following year has much faster growth, greater total leader length, a longer period of rapid growth and is more susceptible to 2,4-D than untreated shrubs (Roundy and others 1981; Cluff and others 1983). Over 90 percent control of both greasewood and salt rabbitbrush was obtained by spraying 2.9 lb/acre (3.3 kg/ha) of 2,4-D in mid-June one year and respraying with 2.0 or 2.9 lb/acre (2.2 or 3.3 kg/ha) of 2,4-D in mid-June the following year (Cluff and others 1983). Respraying appears to be the only way to obtain complete control of sagebrush, greasewood and rabbitbrush on xeric sites.

Table 1.--Some common salt desert plants and associated edaphic factors and plant tolerances.

Scientific Name	Common Name	Edaphic Factors and Tolerances
Allenrolfea occidentalis	Pickleweed	Very high salinity, surface soil stays saturated through summer due to shallow water table.
Artemisia tridentata	Big sagebrush	Low salinity, higher precipitation than shadscale. Stunted plants may indicate saline subsoil or shallow hardpan.
Atriplex confertifolia	Shadscale	Lower precipitation than big sagebrush, saline subsoil. Indicates physiological drought (due to salts) or climate drought.
Chrysothamnus nauseosus ssp. *consimilis*	Salt rabbitbrush	Nonsaline to moderately saline soils. Water table 4.9 to 8.2 feet (1.5 to 2.5 m) deep.
Chrysothamnus albidus	White-flower rabbitbrush	Saline soils, shallow water table.
Distichlis stricta	Inland saltgrass	High to low salinity, tolerates higher salinity when the water table is shallow and soil moisture is high. Water table generally no deeper than 8.2 feet (2.5 m).
Elymus cinereus	Great Basin Wildrye	Low to moderately high salinity. Water table generally within 8.2 feet (2.5 m) of surface. Highest production where soil is wet but not saturated through summer.
Kochia sp.		Dry, well drained soils to dry, saline soils with water table deeper than 6.6 feet (2 m).
Nitrophila occidentalis	Nitrophila	High to moderate salinity, shallow water table.
Puccinellia sp.	Alkali grass	High to moderate salinity, shallow water table, surface ponding of water.
Salicornia sp.		High salinity, very shallow water table.
Sarcobatus vermiculatus	Greasewood	Low to high salinity, water table within 14.8 feet (4.5 m) of surface. Surface soil must be well aerated. High tolerance to Na and B.
Sporobolus airoides	Alkali sacaton	Low to high salinity, shallow water table.

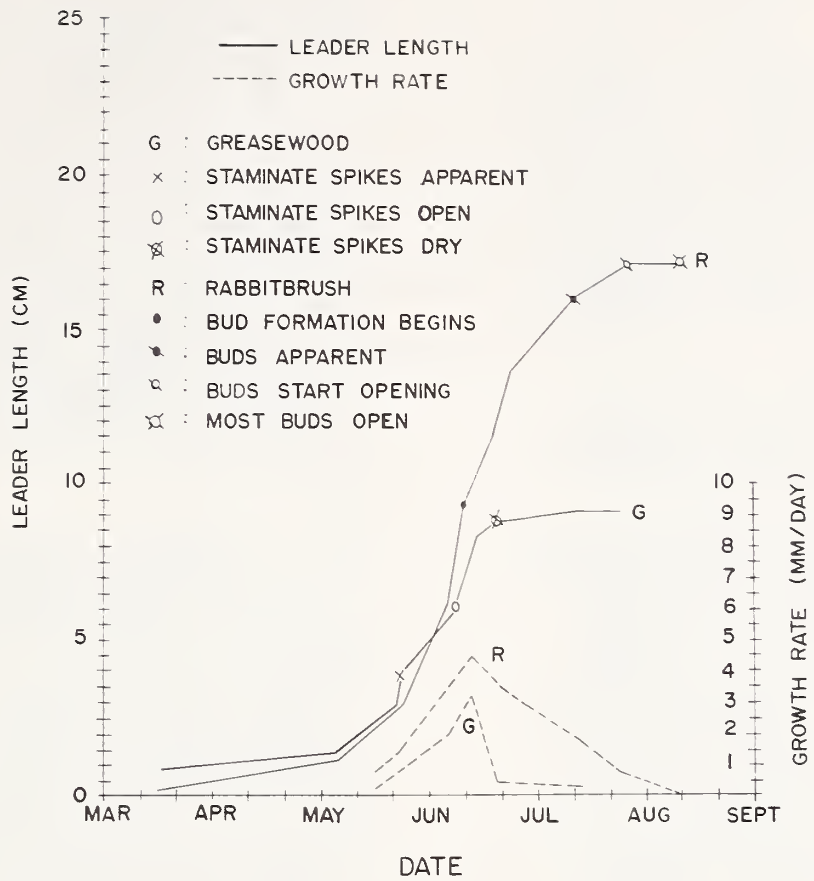

Figure 1.--Vegetative and reproductive phenology of salt rabbitbrush and greasewood in central Nevada in 1979 (Roundy and others 1981).

Table 2.--Control of salt rabbitbrush, greasewood and big sagebrush by 2,4-D applied at the optimum rate of 2.0 lb/acre (2.2 kg/ha) on mesic and xeric sites in 1979 (Adapted from Cluff and others 1983).

Site treated	Soil water potential at 15.7 inches (40 cm) mid-June (MPa)	Brush Mortality (%)			
		Greasewood mid-June	Salt rabbitbrush mid-June	Salt rabbitbrush mid-May	Big sagebrush mid-June
Mesic	-0.5	64a	88a	--	--
Xeric	-1.5	33b	66a	91a	27a

[a]Means for a species followed by the same letter are not significantly different at the 0.01 level of probability, as determined by Duncan's multiple range test.

White-flowered rabbitbrush was very tolerant of herbicides, even when applied 2 years in a row. Sites dominated by this shrub should not be sprayed for brush control.[2]

Rubber rabbitbrush is only partially controlled by burning but is more susceptible to 2,4-D after burning (Robertson and Cords 1957). Greasewood has been reported to resprout following burning (Sheeter 1968). Because greasewood that has resprouted following herbicide application is more susceptible to 2,4-D (Cluff and others 1983) it may be hypothesized that shrubs resprouted following burning may also be more susceptible to 2,4-D than untreated shrubs.

Partial control of sagebrush, greasewood or rabbitbrush will result in rapid redominance by these shrubs. Salt rabbitbrush has high potential to colonize disturbed areas. It produces an average of 13,500 achenes per plant which are easily disseminated by wind due to the capillary bristles of the pappus (Roundy and others 1981). Greasewood shrubs surviving partial brush control respond reproductively to the removal of competition. Only 20 percent of the greasewood shrubs in an undisturbed stand produced seeds while in an adjacent area of partial brush control, 43 percent of the resprouted shrubs produced an average of 250 seeds per plant (Roundy and others 1981). In an area in which 50 percent of the shrubs were controlled 4 years earlier average numbers of seedlings exceeded those in adjacent, untreated area by 2,428, 28,329, and 2,023 per acre (6,000, 70,000, and 5,000 per ha) respectively, of big sagebrush, salt rabbitbrush and greasewood.[3]

FORAGE RELEASE POTENTIAL

Great Basin wildrye is sensitive to spring clipping and frequent herbage removal during the growing season (Krall and others 1971; Perry and Chapman 1974, 1975, 1976). Response of wildrye to brush control and grazing management is currently being studied in central Nevada (Roundy and others 1983). Tiller counts and excavations of small plants on good condition, brush controlled and overgrazed sites indicate that after brush control and rest (1) natural seedling establishment of wildrye in severely depleted stands is very low so these stands are slow in coming back to productive potential (2) severely grazed stands consist of only a few plants which probably grew within shrub canopies and were less accessible to grazing animals and (3) stands with a good understory of wildrye respond rapidly to grazing management and brush control probably by increased tillering and rhizome growth of existing plants. More research is needed to fully understand the release potential of wildrye. It is quite certain that unless brush control is followed by grazing management of wildrye no forage release can be expected.

Proper grazing management of wildrye includes grazing only in fall and winter after the growing season or grazing moderately (less than 50 percent) during the growing season. Grazing of wildrye during the boot stage should especially be avoided (Krall and others 1971).

Little is known of the response of saltgrass, alkali sacaton and other associated forage species to brush control. Growth of forage on saline/arid soils is probably most limited by low soil matric and osmotic potentials. Higher soil water potentials, a longer period when soil water is available to forage plants, and subsequent higher forage production would be expected following brush control due to greatly reduced transpirational soil water loss.

RANGE SEEDING

Many greasewood/salt rabbitbrush communities that may or may not include big sagebrush have a high potential for forage production. Communities that have little understory forage will never produce up to potential until brush is controlled and forage species are reestablished by seeding. Limitations to seedling establishment include low soil matric and osmotic potentials due to high salts, low precipitation and low soil infiltration rates, hard soil crusts, and possibly toxic ion concentrations. Nonsaline, dry soils (electrical conductivity of the saturation extract or ECe less than 4 mmhos) can be seeded to drought-tolerant crested wheatgrass (see Haas and others 1962).

Moderately saline soils (ECe 4-15 mmhos) should be seeded to salt tolerant species such as alkali sacaton, creeping, basin and Russian wildrye, western, streambank and tall wheatgrass and tall fescue (Hafenrichter and others 1968, Plummer and others 1968). Tall wheatgrass and Russian and basin wildrye have greatest potential for seeding saline, arid rangelands. Although these grasses have greater drought or salinity tolerance than most forage species each has certain limitations. Tall wheatgrass is very salt tolerant but requires 11.8 to 13.8 inches (30 to 35 cm) annual precipitation on nonirrigated land (Hafenrichter and others 1968, Vallentine 1961). Basin wildrye and tall wheatgrass seeded on soils with an ECe greater than 15 mmhos have emerged under irrigation but failed to establish (Rollins and others 1968). An improved cultivar of basin wildrye called 'Magnar' recently released by the Soil Conservation Service has much higher germination and seed fill than other seed collections of wildrye (Evans and Young 1983). Research is currently underway comparing germination, salinity and drought tolerance of 'Jose' tall wheatgrass and Magnar basin wildrye. Although Magnar wildrye germinates better than other wildrye collections at reduced osmotic potentials, it has much lower germination than Jose tall wheatgrass at the low osmotic and matric potentials which are characteristic of saline, arid soils (Roundy and others 1982). Magnar requires greater and

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[2] Roundy, B. A. Reno, NV: Data on file with USDA/ARS; 1978 and 1979.

[3] Roundy, B. A. Reno, NV: Data on file with USDA/ARS; 1979.

more frequent precipitation or irrigation in the spring than Jose to produce an acceptable stand of seedlings (Roundy 1983a). Both Magnar and Jose seedlings are tolerant of high sodium concentrations but Jose is more tolerant to high B concentrations[4] and less sensitive than Magnar to decreasing soil osmotic potentials (increasing ECe) due to salts (Roundy 1983b).

Salt tolerance indices (ECe where 50 percent reduction in yield occurs) were 18 and 13 mmhos for Jose and Magnar shoots and 12 and 14 mmhos for Jose and Magnar roots, respectively. Although tall wheatgrass appears better able to establish on saline, arid soils than basin wildrye, established stands of wildrye endure longer periods of summer drought (Hafenrichter and others 1968) and, therefore, will probably persist on more droughty soils than tall wheatgrass.

Russian wildrye is very drought resistant (Hafenrichter 1968) and has produced well in saline soils (Rauser and Crowle 1963) but is very difficult to establish due to poor seedling vigor (Hafenrichter and others 1968; Vallentine 1961). Until plant materials with greater drought and salinity tolerance are available, the seeding of saline, arid rangelands without irrigation is risky. Seeding without irrigation is recommended only on sites with an ECe less than 15 mmhos and that receive 11.8 to 13.8 inches (30 to 35 cm) annual precipitation with 3.9 to 5.9 inches (10 to 15 cm) precipitation between April and June. Basin wildrye and tall wheatgrass established on sites where their roots tap the capillary fringe of the water table could be highly productive. The more mesic the site and the higher the precipitation during winter and spring following fall seeding, the greater the establishment will be on moderately saline rangeland soils. The fine-textured, lowland soils of greasewood communities should be seeded with a minimum of soil disturbance with a standard rangeland drill and shallow furrows. Plowing these soils and seeding them with a deep-furrow drill may cause the soil to flow when saturated from winter storms and result in excessive seed burial and formation of a hard soil crust and possibly bring up salts from lower depths.

SUMMARY AND RECOMMENDATIONS

1. Greasewood and saltgrass sites are highly variable in salinity, drainage, soil water potential, and associated plants.

2. Sites with greatest potential for forage improvement generally have an understory of basin wildrye, saltgrass or alkali sacaton and an overstory of greasewood, salt rabbitbrush and sometimes big sagebrush.

3. Greasewood and salt rabbitbrush can best be controlled on mesic sites by spraying with 2.0 lb/acre (2.2 kg/ha) 2,4-D the first 3 weeks of June when both shrubs are growing rapidly. On xeric sites complete control of greasewood and rabbitbrush may require a respray in June the following year. On xeric sites control of sagebrush, greasewood, and salt rabbitbrush may only be possible by spraying in early May one year to control sagebrush and respraying one and possibly two years later in June to control greasewood and rabbitbrush.

4. Sites with a good understory of wildrye will respond rapidly to brush control and management where grazing is restricted to fall and winter.

5. Sites with a poor wildrye understory must be seeded to improve forage production since natural seedling establishment is very low. Nonsaline and xeric sites (ECe less than 4 mmhos) should be seeded to crested wheatgrass. Tall wheatgrass and Magnar basin wildrye are recommended for seeding in soils with ECe of 4 to 15 mmhos and which receive a minimum of 11.2 inches (30 cm) precipitation with 3.9 inches (10 cm) between April and June. Seeding drier or more saline sites may require irrigation to be successful.

6. Mesic, nonsaline or moderately saline greasewood/saltgrass sites have high potential for forage production after successful range improvements and proper grazing management.

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RESPONSE OF UNDERSTORY SPECIES TO TREE HARVESTING AND FIRE IN PINYON-JUNIPER WOODLANDS

Richard L. Everett and Steven H. Sharrow

ABSTRACT: Fire and tree harvesting have been used successfully to increase understory production of pinyon-juniper woodlands when applied at the proper seral stage. Natural response is variable among sites and exhibits multiple entrance points into the successional model. Burning and tree harvesting stimulate reestablishment of early-to-midsuccessional species within the pinyon-juniper successional process.

INTRODUCTION

Understory cover in pinyon-juniper woodlands has declined dramatically over the last few decades because of increasing tree dominance (Blackburn and Tueller 1970; Tausch and others 1981). Unfortunately for both livestock and wildlife, the forage base has declined even faster. On some sites one-third of understory production has been lost when trees are still less than 6.6 feet (2 m) in height (West and others 1979) and herbage yields may decline by 82 percent when tree canopy cover exceeds 50 percent (Arnold and others 1964).

Removal of trees is imperative for forage improvement, but indiscriminate destruction of trees to release the understory wastes the tree resource. Tree products, such as cordwood, charcoal, Christmas trees, and nuts have economic value and a good case has been made for their management (Johnson 1975). Jensen's (1972) work in the House Canyon pinyon-juniper management unit of central Nevada demonstrated both tree and forage resources could be improved through appropriate silvicultural practices. Modern silvicultural (Meeuwig and Bassett[1]) and range management (Evans and others 1975) practices recognize site quality differences for tree and forage production and recommend small (<5 acres [2 ha]) treatment areas following an intensive site selection process.

Where woodlands are managed for both forage and wood products, forage may be enhanced in a patchwork of small treated areas. Economic and topographic constraints make small treatment sites unamenable to mechanized seeding, thus natural plant response must improve the forage base. Understory establishment and growth can be expected following release from tree competition as indicated by pinyon-juniper successional models (fig. 1). These models suggest basic trends in plant succession, however, plant response on a particular site is not totally predictable. A site is a composite of subsites (microsites), each with its own sere and rate of successional advancement.

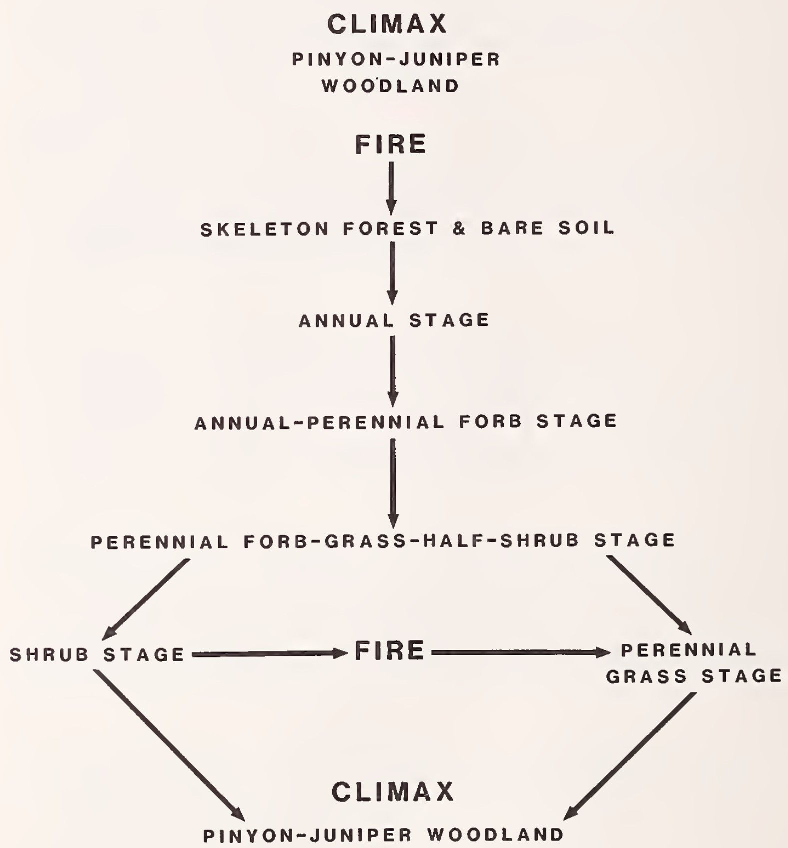

Figure 1.--Pinyon-juniper succession following fire (Arnold and others 1964).

Richard L. Everett is Range Scientist at the Intermountain Forest and Range Experiment Station, USDA Forest Service, Reno, Nev. Steven H. Sharrow is Associate Professor of Range, Department of Rangeland Resources, Oregon State University, Corvallis.

[1]Meeuwig, R. O.; Bassett, R. L. Pinyon-juniper. Revision of silvicultural systems for the major forest types of the United States. Agric. Handb. 445. Washington, D.C.: U.S. Department of Agriculture; In press.

DISCUSSION

Competition Between Tree and Understory Species

Plant response following tree release is influenced by the tree-induced effects that caused understory decline. Tree effects on understory vary with tree species, associated understory species, and site characteristics, thus no one scenario fits all conditions. To avoid confusion and the misinterpretation of findings, both authorship and the predominant tree species in cited studies are given. Dominant tree species discussed are: *Pinus monophylla* (PIMO) singleleaf pinyon, *Pinus edulis* (PIED) piñon, *Juniperus osteosperma* (JUOS) Utah juniper, *Juniperus monosperma* (JUMO) one-seed juniper, *Juniperus deppeana* (JUDE) alligator juniper, and *Juniperus occidentalis* (JUOC) western juniper. If more than three tree species were covered in a given study, the key (MULT) will be used.

Adjacent trees outcompete most understory species for soil moisture (Jeppesen 1977 [JUOC]), light (Jameson 1966 [JUMO]), and nutrients (Barth 1980 [PIED]), thus understory declines as succession proceeds. In dense stands ubiquitous tree roots (Woodbury 1947 [MULT]; Plummer 1958 [PIED - JUOS]) cause rapid surface soil moisture withdrawal from all soil microsites--the duff (thick needle mat) under the crown, transition zone adjacent to the tree crown, and the interspace between trees. The tree species competitive advantage is partly due to the utilization of soil moisture prior to the breaking of dormancy of many understory species (Jeppesen 1977 [JUOC]) and the presence of a tap root that withdraws moisture at a depth unavailable to grass species (Emmerson 1932 [PIED - JUMO]).

As trees increase in size and the stand thickens, the duff under the tree crown occupies much of the ground surface (≅50 percent; Everett and Koniak 1981 [PIMO]). A dense needle mat >10 m^2 in area under a single large singleleaf pinyon is not uncommon. Duff visibly delineates an area of nutrient enrichment (Barth 1980) at the expense of interspace soils and associated understory.

Pinyon litter physically reduced understory plant establishment; shading or allelopthic effects reduced understory persistence under the tree crown. In time, the understory is displaced from the tree stem of singleleaf pinyon and one-seed juniper (Johnsen 1962). We found understory cover declined in the interspace between adjacent singleleaf pinyon trees, increased at the crown edge, and became negligible under the dense crown (Everett and others[2] [PIMO]). Understory cover as a whole declined with increased tree cover, but the transition zone adjacent the tree crown became somewhat more "favorable" for understory growth under these conditions. Plummer (1958) reported opposite understory distribution patterns associated with pygmy conifers in Utah, thus no one scenario will fit all understory-overstory species combinations.

Understory species are not equally suppressed by tree competition and this results in discernible species zones around the tree stem (Arnold 1964 [JUMO]; Johnsen 1962 [JUMO]). Several cool season grasses (*i.e.,* prairie june grass *Koelaria cristata*; western wheatgrass *Agropyron smithii*; bottlebrush *Sitanion hystrix*; mutton bluegrass *Poa fendleriana*) are more abundant under or adjacent the tree crown of alligator juniper than in the interspace between trees (Clary and Morrison 1973). We found Sandberg bluegrass (*Poa sandbergii*) only grudgingly displaced from singleleaf pinyon duff while prostrate forbs were readily expelled. These preexisting species patterns at the time of either burning or harvesting treatments are reflected in post-treatment response as discussed later.

Tree Harvesting and Prescribed Burning Treatment

The literature is replete with reports of increased understory cover and production following tree removal by hand chopping, chaining, herbicides, and prescribed burning (Arnold and Schroeder 1955 [MULT]; Aro 1971 [MULT]; Clary and others 1974 [JUDE - JUOS]; Evans and others 1975 [PIMO]). Mechanical treatments are applicable when planted seed must be covered to establish desirable species and exclude invaders (*i.e.,* cheatgrass *Bromus tectorum*).

Where seeding or seed covering is not required, prescribed burning can be less expensive than mechanical or chemical treatment (Blackburn and Bruner 1975 [PIMO - JUOS]). Hand-harvested wood can provide a cash crop in itself, and cleared areas provide transitory range. Thus burning and wood harvesting are two viable alternatives for forage improvement. The choice between the two treatments is decided by future use of the site, economic value of the wood, and stand physiognomy.

Controlled burns require an understory adequate to carry fire (Bruner and Klebenow 1979 [PIMO - JUOS]; Richard Young,[3] this symposium [JUOC]), thus early-to-midsuccessional stands are usually burned. Prescribed burning has been used successfully to increase understory production and to eliminate tree species (Barney and Frischknecht 1974 [JUOS]; Dwyer and Pieper 1967 [JUDE]) and was selected by Aro (1971 [MULT]) as the optimum conversion method where practical. Closed stands lack understory necessary for

[2]Everett, R. L.; Sharrow, S. H.; Meeuwig, R. O. Pinyon-juniper woodland understory distribution patterns and species associations. Submitted to Torrey Botanical Club Bulletin.

[3]Young, R. P. The use of fire to control and improve wildland sites.

controlled burns, but are more easily harvested for cordwood. Hand-cutting has been used effectively to reduce tree competition in Arizona (Arnold and Schroeder 1955 [MULT]) and Oregon (Jeppesen 1977 [JUOC]).

Plant Response Following Tree Harvesting or Prescribed Burning

The character of plant response following burning or tree harvesting is dependent upon the predisturbance level of understory suppression, which varies with tree cover, the tree species, and the soil type (Clary and other 1974 [JUOS - JUDE]; Springfield 1976 [JUMO - JUDE]). The selected conversion technique and resultant site disturbance further alters plant response (Clary and others 1974) such that quantitative response values can rarely be extrapolated from one project to another. Nevertheless, general trends of plant response and their probable causes can provide insight for land managers in the estimation of potential response on future treatment sites.

Plant succession following burning or tree harvesting may tend toward the standard successional model, but post-treatment plant assemblages may depict any number of the early successional stages (fig. 2). Even though pretreatment stands may be similar, initial plant composition of post-treatment communities can vary considerably (Everett and Ward[4]). This is due to the irregular germination of soil seed reserves (Koniak and Everett[5]) and the random immigration of off-site species.

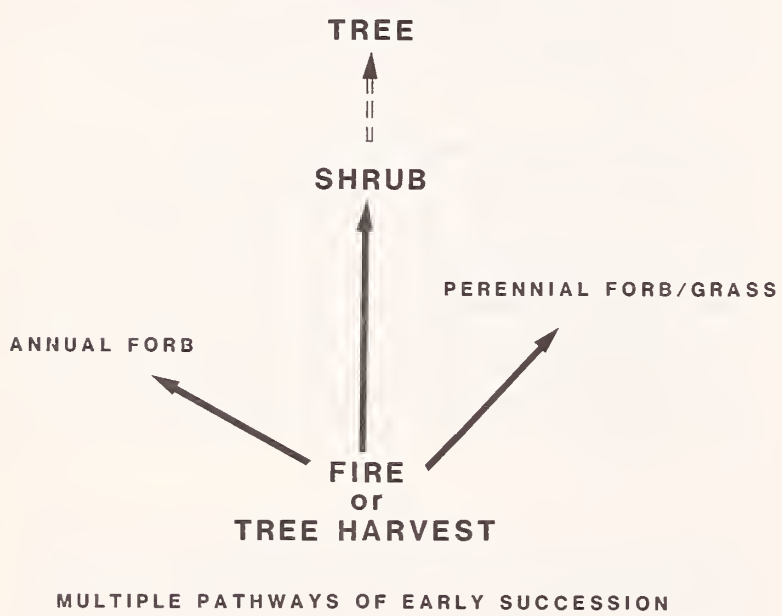

Figure 2.--Natural response following fire or tree harvesting in pinyon-juniper woodlands.

[4]Everett, R. L.; Ward, K. Early plant succession on pinyon-juniper controlled burns. Northwest Sci. In press.

[5]Koniak, S.; Everett, R. L. Soil seed reserves in successional stages of pinyon woodlands. Am. Midl. Nat. In press.

Plant response often varies as much within an array of burn or tree harvest sites as between the two treatments. Precise response is unpredictable for either treatment because of potentially unknown species immigration, soil seed reserves, and post-treatment environmental variables. General plant response may be estimated from soil characteristics such as $CaCO^2$ levels (O'Rourke and Ogden 1969 [JUDE]), soil depth, or stoniness (Stevens and others 1974 [JUOS - PIED]). Elevation, aspect, precipitation, and indicator plant species may also provide an estimate of potential post-harvest response (Stevens and others 1974 [JUOS - PIED]; Winward[6]). The qualitative character of succession is predetermined at an early stage on many sites because of the presence of numerous plant forms, including many midsuccesssional species (Everett and Ward[4]).

Following burning, number of understory species increases because of the rapid return of pretreatment species together with the establishment of numerous fire-induced species (Everett and Ward[4]). This result could be expected from Nabi's (1978) report that species numbers decline as pinyon-juniper succession proceeds. Tree harvest of fully stocked stands did not dramatically increase species numbers because soil seed reserves were low and few understory plants remained when succession had proceeded this far (Everett 1978; Koniak and Everett[5]).

Understory species provided approximately 30 percent ground cover 5 years following prescribed burning (Everett and Ward[4] [PIMO]), but less than 9 percent cover following tree harvesting on fully stocked singleleaf pinyon stands. Greater understory response following burning was expected because predisturbance understory cover on burns (38 percent) was 10 times greater than predisturbed understory on tree-harvested (3 percent) plots.

Increases in forage production following fire of 400 to 1100 lbs/acre (448 - 1232 kg/ha) have been reported by Aro (1971 [MULT]). Similar increases in herbage production following tree harvesting have been reported by Arnold and Schroeder (1955 [MULT]), Clary (1974 [JUDE]), and Springfield (1976 [MULT]). Herbage production can continue to increase for 13 years following tree harvest (Arnold and others 1964 [MULT]), but response is site and year specific (Clary 1974 [JUDE]). No increase in herbage production following tree removal has been noted on some sites (O'Rourke and Ogden 1969 [JUDE]; Clary and others 1974 [MULT]). Unfavorable moisture regimes and the absence of understory species capable of utilizing released resources were suggested causes for the lack of response.

[6]Winward, A. H. Using sagebrush ecology in management of wildlands. In: Proceedings, Utah Shrub Ecology Workshop; September 1981. In press.

Plant response is not uniform within treated sites partly because of the various soil microsites present and the pretreatment plant distribution patterns. Burned duff zones have remained devoid of vegetation much like the burned slash piles following mechanical treatments (Arnold and others 1964 [MULT]). Thus plant response has been most rapid in the microsites between the trees on harvest plots.

On tree harvest sites with a contiguous grass understory, response has been greatest at the crown edge. Increased soil moisture storage and nutrient reserves under the duff promote the vigor of established plants in accord with the preharvest plant distribution patterns discussed earlier. Where understory is more sparse, response is less orderly because of the random location of remnant plants, soil seed reserves, and plant establishment from off-site immigration.

CONCLUSIONS

In pinyon-juniper woodlands, understory declines dramatically under intense tree competition for soil moisture, light, and nutrients. Thus, attempts to improve forage by grazing management alone are unsuccessful. Prescribed burning and tree harvesting at different seral stages have generally increased herbaceous growth but response varies considerably. Attempts to predict post-treatment response based on standard successional models have failed because of the multiple entrance points into the successional model and the absence of specific seral stages as succession proceeds. Response has been most fruitful when desirable species already present were capable of utilizing released resources and occurred in sufficient quantities to do so.

Cover and productivity of understory are not uniform across treatment sites following tree removal, but reflect pretreatment plant distribution patterns, and an array of soil surface microsites that vary in available soil nutrients. Response on grossly similar sites, that vary in the proportion of each soil microsite, may well be qualitatively but not quantitatively similar.

Understory response to burning in midsuccessional stands can be more rapid than to tree harvesting of fully stocked stands due to the negligible understory of the latter sites. Where understory is more vigorous, post-harvest understory response provides substantial increases in forage.

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METHODS FOR IMPROVING MOUNTAIN MEADOW COMMUNITIES

Richard E. Eckert, Jr.

ABSTRACT: Mountain meadow communities are not producing to their potential. This paper describes five ways to improve these communities for livestock, wildlife, and site stability. Methods discussed are weed control and seeding, iris control, tree and shrub transplants, check dams, and grazing management.

INTRODUCTION

Mountain meadow communities occur adjacent to streams and springs in mountainous terrain. Deep fertile soils and good soil moisture from a seasonal water table contribute to a vegetative composition much different from, and with a productive potential much greater than, adjacent upland rangeland. Most meadow communities are classified as Wet Meadow Range Sites by the Soil Conservation Service. Sites in a high seral stage are dominated by tufted hairgrass (Deschampsia cespitosa). Sites in lower seral stages are dominated by Kentucky bluegrass (Poa pratensis), Nevada bluegrass (P. nevadensis), slender wheatgrass (Agropyron trachycaulum), meadow barley (Hordeum brachyantherum), mat muhly (Muhlenbergia richardsonis), sedges (Carex sp.) and rushes (Juncus sp.). Common forbs are Rocky Mountain iris (Iris missouriensis), western yarrow (Achillea lanulosa), common dandelion (Taraxacum officinale), mountain dandelion (Agoseris sp.) and cinquefoil (Potentilla sp.). Communities are small, ranging from several hundred square feet to several hundred acres. However, species composition and productive potential make these areas important sources of forage and water for livestock (Phillips 1965; Cook 1966) and game habitat (Patton and Judd 1970; Ames 1977; Hubbard 1977).

Richard E. Eckert, Jr. is a Range Scientist with the USDA Agricultural Research Service at the Renewable Resources Center, University of Nevada, Reno.

Under season-long grazing, meadows generally are areas of livestock concentration. Roath and Krueger (1982a) reported that although the riparian zone constituted only 1.9 percent of the area of one allotment, it produced 81 percent of the vegetation removed by cattle. Fecal analysis from cattle grazing an allotment in northern Nevada showed that animals obtained up to 88 percent of their diet, depending on season of use, from species found on the wet meadow range site that occupies less than 1 percent of the allotment.[1]

Because of past mismanagement, many meadow communities are not producing to potential for livestock or wildlife, nor is the present cover protecting the site. The degree of mismanagement is reflected by different seral stages found today. Meadows in a very low seral stage are characterized by channel entrenchment and head cutting, loss of desirable species, increase and invasion by undesirable species, and loss of productivity. Meadows in a mid seral stage have a remnant stand of desirable species but productivity is suppressed by herbaceous weeds such as Rocky Mountain iris. Meadows in a high seral stage have a full stand of desirable species, but maximum productivity is reduced because of improper grazing management.

In this paper, research on improvement of meadow communities for livestock, wildlife, and site stability is reviewed and updated with the results of meadow restoration work conducted in Nevada from 1964 to 1972.

WEED CONTROL AND SEEDING

Good weed control is essential for establishment of a productive stand of seeded species. Cornelius and Talbot (1955), Plummer and others (1955), Rummell and Holscher (1955), Eckert and others (1973a), and Eckert (1975) all found that weedy vegetation such as sedge, poverty weed (Iva axillaris), and cheatgrass (Bromus tectorum) was best controlled by a summer-fallow treatment. Eckert and others (1973a) described the reduction in competition that is possible with an effective summer fallow (table 1). This method of weed control is usually accomplished by plowing in late spring or early summer when sod-forming species have begun growth and after weed seeds have germinated. Prior to seeding in the fall, the sod is broken down and a seedbed prepared by use of a disk harrow or similar equipment.

[1] Richard E. Eckert, Jr. Reno, NV: Data on file at USDA, Agricultural Research Service, Renewable Resource Center; 1980.

Table 1.--Yield of competitive vegetation during the seedling year on the check and summer fallow treatments on cheatgrass-poverty weed and sedge sites.

Weed control treatments	Species yield	
	Cheatgrass	Sedge
Cheatgrass-poverty weed site	----------------lb/acre-----------	
Check	[1] 3000a	0b
Summer fallow	1800a	0b
Sedge site		
Check	0a	580a
Summer fallow	320a	0b

[1] Species means within site followed by different letters are significantly different at the 0.1 probability level as determined by Duncan's multiple range test.

Success of seeding in deep furrows has been demonstrated by Eckert and Evans (1967) in the sagebrush type, by Hull (1970) at high elevations, and by Eckert and others (1973a) in mountain meadows. Deep furrows can be made with shovel-type openers or with a rangeland drill equipped with deep-furrow arms (Asher and Eckert 1973).

Species and cultivars used to revegetate mountain meadows should be adapted to the site and to the proposed use of the new vegetation. Stewart and others (1939), Pickford and Jackman (1944), Cornelius and Talbot (1955), Plummer and others (1955), and Rummell and Holscher (1955) suggested species adapted to meadow communities throughout the western United States. Eckert and others (1973a) evaluated seedling stands and productivity of Amur intermediate (*Agropyron intermedium*), Luna pubescent (*A. intermedium* var. *trichophorum*), Primar slender wheatgrass; Regar bromegrass (*Bromus biebersteinii*); Alta tall fescue (*Festuca arundinacea*); Eski sainfoin (*Onobrychis viciifolia*); and Ladak alfalfa (*Medicago sativa*). These species were planted in the fall, in furrows, on a summer-fallow weed control treatment. Legumes were evaluated as possible food plants for sage grouse (*Centrocercus urophasianus*). Seedings were made on two sites: one dominated by cheatgrass and poverty weed; the other by sedges.

Acceptable stands of pubescent and intermediate wheatgrasses were obtained on both sites. The cheatgrass-poverty weed site averaged 2.0 plants/ft of row (6.6 plants/m of row) while the sedge site averaged 3.2 pfr (10.5 pmr). However, stands of Regar bromegrass, Alta fescue, and slender wheagrass were much poorer on the former site and averaged only 0.7 pfr (2.3 pmr) compared with 3.1 pfr (10.2 pmr) on the latter site. This difference was probably due to the greater amount of competitive vegetation on the cheatgrass-poverty weed site than on the sedge site (table 1). This response indicates that meadow improvement by seeding should be done before a site is severely depleted to the cheatgrass-poverty weed stage.

Alfalfa and sainfoin averaged 1 plant per 3.6 and 2.8 ft (1.1 and 0.8 m) of row, respectively. Based on estimated herbage production and quality, such a legume stand appears to satisfy the quantity and quality food requirements for a sage grouse population studied by Oakleaf (1971).

On a cheatgrass-poverty weed site, pubescent and intermediate wheatgrasses were the most productive species (table 2). On a sedge site, pubescent wheatgrass was the most productive seeded species. Both wheatgrasses produced more on the cheatgrass-poverty weed site than on the sedge site. Stands were mostly full and most environmental factors were similar. However, depth to the water table varied considerably (table 2). Capillary rise above a 4.7 ft (1.4 m) water table could increase the amount of soil moisture available to plants on the cheatgrass-poverty weed site. On the sedge site, a deep gully lowered the water table and the capillary fringe to below rooting depth early in the growing season so that the productive potential was reduced from a meadow environment to a dryland environment.

IRIS CONTROL

Iris is a common plant of native meadows and pastures. However, dense stands can be a serious problem on poorly managed meadows. Iris is unpalatable to livestock (Pryor and Talbert 1958), reduces forage production through competition, and has no value as a wildlife food plant (Gullion 1964). Rootstocks enable the plant to withstand heavy trampling and to spread rapidly when competitive vegetation is weakened (Dayton 1960).

Pryor and Talbert (1958), Cords (1960, 1972), and Robocker (1966) indicated the superiority of 2,4-D for iris control but none of these authors evaluated the effects of this treatment on non-target species. Eckert and others (1973b) and Eckert (1975) evaluated both iris control and the response of nontarget grass and forb species.

Table 2.--Yield of seeded and native species 3 years after seeding on cheatgrass-poverty weed and sedge sites.

Species or cultivar	Yield: Cheatgrass/poverty weed site	Yield: Sedge site
	lb/acre	lb/acre
Luna pubescent wheatgrass	[1] 4230ax	3120ay
Amur intermediate wheatgrass	4000ax	2240by
Regar bromegrass	410cy	1720cx
Alta tall fescue	40dx	690dy
Primar slender wheatgrass	1210b	--
Native slender wheatgrass		[2] 3230
Native sedge		[2] 2290
Range in water table depth (ft) from June-August	4.7-6.8	4.7-12.0
Annual precipitation (in)	23.4	23.4

[1] Means are compared among species and between sites. Means followed by different letters (a through d) vertically or by different letters (x or y) horizontally are significantly different at the 0.05 probability level as determined by Duncan's multiple range test.

[2] Native species were not included in the experimental design. Yields were taken from near-by stands and are presented for comparative purposes.

Excellent iris control was obtained by one application of 2 lb/acre (2.2 kg/ha) to 4 lb/acre (4.5 kg/ha) of low volatile ester of 2,4-D from mid-June or early July. Iris phenology at time of treatment ranged from late vegetative to late bloom. The 2 lb/acre (2.2 kg/ha) treatment in early July gave from 73 to 85 percent control. This treatment appears near the minimum concentration of herbicide needed for excellent iris control.

Iris control significantly increased total yield (table 3) and yield of individual grass and grass-like species in years after treatment (table 4). Iris control on sites dominated by Nevada bluegrass resulted in a yield response of 558 lb/acre (625 kg/ha) by this species the first year after treatment compared to the check of 106 lb/acre (119 kg/ha). During the following 4 years, yield varied between 160 and 502 lb/acre (179 and 562 kg/ha) on the check and between 520 and 1100 lb/acre (582 and 1232 kg/ha) on treated plots. Slender wheatgrass responded slowly, however, after 5 years, production was 800 lb/acre (896 kg/ha).

Oakleaf (1971) calculated that a sage grouse population of eight birds/acre (20 birds/ha) would consume about 10 lb of forbs per acre (11 kg/ha) during meadow occupancy. On this basis, total forb production the year after treatment (table 5) was minimal. Total production the second year appeared adequate for sage grouse needs. However, even though the total forb yield may exceed 10 lb/acre (11 kg/ha), forb composition may not be adequate for good sage grouse habitat.

In addition, total forb yield and species yield can be misleading, because sage grouse do not consume the entire plant but rather remove certain parts. Klebenow and Gray (1968) found that sage grouse chicks preferred the buds and seeds of dandelion over leaves and stems. We do not know the total forb production necessary to supply the required intake of favored plant parts.

Since certain sage grouse food plants are adversely affected by 2,4-D, the land manager must be knowledgeable of vegetation conditions on each proposed project area. In this way he can decide whether or not to treat iris-infested sites, how large an area to treat, and what effects on sage grouse food plants to expect.

TREE AND SHRUB TRANSPLANTS

Some stream banks and meadows now support woody species and there is evidence that trees and shrubs were more prevalent in the past. Reestablishment of such species is one method to stabilize stream channels and check dams, to create wildlife habitat, and to increase esthetic values (Yoakum and Dasmann 1980).

Table 3.--Production of grass, grasslike, and forb species on treated and check plots for 5 years after iris control.

Year	Production Treated	Production Check
	---------------lb/acre---------------	
1966	[1] 490a	210b
1967	1780a	830b
1968	780a	290b
1969	1820a	700b
1970	2300a	940b

[1] Treatment means for total production within year followed by different letters are significantly different at the 0.05 probability level as determined by Duncan's multiple range test.

Table 4.--Production of grass, grasslike, and forb species on treated and check plots in the fifth year after iris control.

Species	Production Treated	Production Check
	---------------lb/acre---------------	
Slender wheatgrass	[1] 800a	470b
Nevada bluegrass	960a	490b
Meadow barley	350a	20b
Other grasses	160a	0a
Sedge	20a	10a
Iris	150b	760a
Common dandelion	30a	40a
Western yarrow	130a	140a
Other forbs	130a	20a

[1] Treatment means for production by species followed by different letters are significantly different at the 0.05 probability level as determined by Duncan's multiple range test.

Table 5.--Forb production the year of treatment and for 2 years after iris control.

	Production				
	1969	1970		1971	
Species	Check	Check	Treated	Check	Treated
	------------------------lb/acre------------------------				
Common dandelion	160	[1] 270a	10b	60a	30a
Western yarrow	250	260a	30b	160a	20b

[1] Treatment means for forb species within years followed by different letters are significantly different at the 0.05 probability level as determined by Duncan's multiple range test.

Tree and shrub species for introduction into meadow communities were evaluated by Eckert (1975). Species tested were American plum (Prunus americana), black chokecherry (Prunus virginiana var. melanocarpa), cardinal olive (Elaeagnus umbellata), common bladdersenna (Colutea arborescens), common lilac (Syringa vulgaris), oldman wormwood (Artemisia abrotanum), golden willow (Salix aurea), Russian olive (Elaeagnus angustifolia), Siberian peashrub (Caragana arborescens), and Tatarian honeysuckle (Lonicera tatarica).

Materials for planting in 1 year were obtained as bare-root nursery stock. Plants were dug in March and April, "heeled in" at a cool, shady location and planted in June when the site was accessible. Plummer and others (1968) strongly recommended spring planting unless supplemental water is available. Container-grown plants were tested in 2 years. Plants were obtained as bare-root nursery stock (1 to 2 years old) in March and April, placed in 1-gallon containers, and planted in June.

About 75 percent of the transplants on barren stream banks or on check dams seeded to crested wheatgrass survived through the 6-year evaluation period. None of the plantings in a dense cover of native grasses and sedges survived through the second year. On barren stream banks and check dams, 55 percent of the trees and shrubs transplanted 6 ft (1.8 m) above the water line survived the first year, but none survived the second year. Survival of transplants on banks 1 and 2 ft (0.3 to 0.6 m) above the water line was 90 percent. However, plants nearer the water were more vigorous. None of the transplants next to reservoirs persisted.

Golden willow and Siberian peashrub were the most successful species on both the stream banks and dam faces. Bladdersenna persisted for 6 years, but did not develop as did golden willow or Siberian peashrub. The other species tested did not survive the evaluation period. Transplants were protected from livestock use for 6 years. After this time, cattle would graze nearby plots of seeded grasses but only lightly browse Siberian peashrub and bladdersenna. Golden willow was not browsed.

CHANNEL STABILIZATION

Mountain meadows developed on alluvial fill along water courses where the slope gradient and stream velocity decreased. As sediment was deposited, vegetation developed from the edges and more sediment was trapped, until the basin was filled and completely vegetated with a mesic plant community (Robertson and Kennedy 1954). These sediments are themselves subject to erosion. Climatic changes, damages to upstream watershed, and geologic changes such as land tilting all increase stream flow, sediment load, and erosion potential. In resource management, we want to maintain meadow integrity for livestock forage, wildlife habitat, watershed stability, and esthetics.

Water control structures, such as check dams, may be one method to halt channel cutting, prevent further site deterioration, and improve meadow condition. Structures should (1) reduce the channel gradient and erosive power of the stream, (2) collect sediment to fill the channel, and (3) raise the water table in the adjacent riparian zone.

Check dams were evaluated in Nevada from 1965 to 1973 (Eckert 1975). All structures were designed to impound about 1 acre ft (1233 m^3) of water. Two structures did not hold water through July or August. One dam held water through the summer in all years (fig. 1). Two structures did not hold water the first 2 years after construction but did contain some water through the summer and fall of the other 7 years. The small average amount of sediment collected behind the structures each year indicated that channel filling can be a very slow process. The exception would be in years of catastrophic runoff, such as in 1973, when 4 ft (1.2 m) of sediment filled one reservoir.

Figure 1.--An effective check dam in a 7-ft deep channel.

Direct evaluation of the effects of structures on the water table could not be made because no measurements were taken before construction. However, water-table measurements in relation to channel depth, proximity to the channel, and water control structures gave an indirect evaluation (Eckert 1975). By early summer, the water table in a 12 ft (4.5 m) deep channel without an effective dam was below the root zone of herbaceous species. This site was a dryland environment dominated by sedge and cheatgrass, with some big sagebrush (Artemisia sp.) and rabbitbrush (Chrysothamnus sp.). After a deep channel is cut, an effective dam was necessary to restore the water table to the level required by mesic meadow species. A higher and more static water level resulted from a reservoir influence than from a stream influence.

GRAZING MANAGEMENT

Whether meadow communities have native or improved vegetation, some form of management is necessary to prevent the livestock concentration and heavy use during the growing season that occurs under season-long grazing. Some of the management techniques discussed may have no documented value for improving vegetation conditions of meadow communities, the focus of this paper. This does not imply that the same techniques are not valuable for improving some other parts of the riparian ecosystem, such as stream channels and stream banks.

We lack information about the kinds of grazing management appropriate for meadow communities and about species responses to different management schemes. This knowledge gap is due to two factors: a general lack of interest in grazing systems research until recent years and an indifference about the conditions on small riparian areas as compared to large upland sites. This situation has now changed because of emphasis on grazing management as a method for range improvement and because of the legal requirements for proper management of riparian ecosystems.

Although the emphasis on management of riparian ecosystems has increased, few results are available because of the time required to produce these results. The results available can be catagorized as: 'word of mouth', qualitative information, and quantitative data. We have all heard agency personnel or ranchers comment on the value of a certain kind of grazing management for the riparian zone on a certain allotment or ranch. When trial and error systems are used, some kind of quantitative information should be collected to add to our minimal knowledge of the subject.

The Camp Creek Study in central Oregon (Winegar 1977) is an example of qualitative information about vegetation response to fencing. This study was not intended to be a research project. The channel was fenced in 1965 and various species were planted or seeded. After 9 years the introduced species had become established and native species had shown excellent growth. Of the 45 species indentified within the protected area, only 17 were known to be present before fencing. No information on changes in plant cover, yield, or density was presented.

Duff (1979) made a qualitative evaluation of vegetation recovery in a fenced riparian area. Grasses and willows showed a favorable response after 4 years of non-use. However, after only 6 weeks of grazing by trespass cattle, the vegetation was degraded to pre-exclosure conditions. After 4 more years of rest, grasses, sedges, and willows had recovered again. Few data were presented on vegetation changes inside the exclosure, but no data were given for the continuously grazed areas.

A number of stream channels have been fenced to evaluate complete protection as a means for managing and restoring the riparian system including meadow communities. However, most results about meadow improvement are based on observations and photographs. Without some quantification of vegetation trend, one could logically question whether the differences observed are due to changes in species composition or only utilization effects.

Three literature sources were examined for results of quantitative studies of management systems on meadow communities. These sources were: Hickey (1967), McDaniel and Allison (1980), and Allison and Wood (1981). Only one reference was found. Johnson (1965) studied the effects of rotation, rest-rotation, and season-long grazing on a mountain range in Wyoming. Vegetation of meadow communities on this range consisted of sedges, rushes, Kentucky bluegrass, tufted hairgrass, and bluejoint reedgrass (Calamagrostis canadensis). On the basis of vegetation changes from 1958 to 1961, the author concluded that either rotation or rest-rotation management would benefit cattle range. Under these two management systems utilization was reduced without any reduction in the number of animals grazed, grazing use was more uniform, total cover increased, cover of desirable forage species increased, and cover of poor forage species decreased. When all changes were analyzed, range improvement appeared to be more rapid under rest-rotation management than under simple rotation grazing. However, both types of management were superior to season-long grazing. I question whether an adequate interpretation of grazing systems can be made on the basis of a 3-year study.

Additional information on management of meadow communities was found in the literature. Hayes (1978) evaluated the effects of rest-rotation grazing on high mountain meadows in central Idaho from 1975 to 1977. Emphasis was on streambank stability. One meadow managed under rest-rotation management since 1962 appeared to be a stable community in good condition. The condition of a meadow managed under rest-rotation grazing since 1973 ranged from fair to good. The presence of several species common to high-condition meadows and establishment of vegetation along trails and around watering sites indicate improving range condition. No data were presented, however, to validate vegetation trend from the start of rest-rotation management through 1976.

Ratliff (1972) measured herbage yield and species composition under free choice and rest-rotation management in mountain meadows of northeastern California. The five-unit system was based on the growth and reproductive requirements of Idaho fescue. The significantly greater herbage yield of 512 lb/acre (573 kg/ha) on the rest-rotation treatment was due to a significant increase in production of grass-like species. Management on the area began in 1954, but the author did not state when the yield and composition data were collected.

Three studies dealt with management of Kentucky bluegrass in Oregon. Kentucky bluegrass has become established as the dominant species in native meadow communities as the result of overgrazing and subsequent site deterioration (Volland 1978). This species is also the dominant species on high elevation meadows throughout the western United States. Volland (1978) stated that maximum production by Kentucky bluegrass cannot be achieved under season-long use. He found that complete protection by fencing increased yield through the sixth year. But, yield after 11 years of rest was not different than on adjacent areas of season-long use. Based on these results, the author concluded that resting a management unit for 6 consecutive years was not a practical way to regain vigor and productivity of this species. He suggested a management system of alternate periods of rest and grazing to promote leaf development of the tillers, reduce flowering of tillers, and maintain plant vigor. The phenological time to accomplish this on his study area was mid-May. If the time to graze is similar on other areas in the West, cattle management will be difficult because of accessibility problems early in the spring and because of damage to wet soil.

Roath and Krueger (1982a) studied the influence of cattle grazing on a mountain riparian zone in Oregon on both the dry and wet meadow types. Kentucky bluegrass was the most important herbaceous species. Mountain alder (Alnus incana), willow, and red-osier dogwood (Cornus stolonifera) were the important shrubs. Utilization of shrubs was lowest when herbaceous vegetation was lush but tended to increase as the season progressed and herbaceous vegetation matured. The authors theorized that a management system which used the herbaceous component early in a deferred system would benefit the shrub component. This action could have a negative effect on the herbaceous species, although Kentucky bluegrass grazed at 72 to 76 percent utilization over a 2-year period showed few negative cover or vigor effects. A late season of use would minimize negative effects on the herbaceous species but could increase utilization of shrubs. A longer study period is needed to test the assumptions made by the authors and to follow changes in the stand of Kentucky bluegrass grazed at these high intensities.

Roath and Krueger (1982b) conducted a 2-year study of cattle grazing and behavior on a forested range in Oregon that contained a small acreage of meadow communities dominated by Kentucky bluegrass. Based on home-range groups of cattle, the authors suggested two cattle-management techniques to reduce grazing pressure on the riparian zone. Cattle known to belong to the home-range group on the riparian zone could be culled from the herd and the home-range group on the uplands kept for breeding purposes. New animals could be herded to upland areas and behaviorally-bonded to these areas if forage, water, and salt were available.

Claire and Storch (in press) suggested the use of special pastures for separating grazing use in the riparian zone from grazing on the uplands. Grazing usually would be deferred until late in the growing season.

The effects of late-season use on meadow vegetation in Wyoming was evaluated by clipping to simulate grazing (Pond 1961). Herbage removal at a 1-inch (2.5 cm) stubble height every 2 weeks during the growing season decreased the density and productivity of native grasses and sedges. Herbage removal at the end of the growing season had little effect on the density of native species, but production was reduced.

Kauffman (1982) studied the synecological effects of late-season grazing on different riparian communities under actual cattle use. Comparisons were made between late season use (late August to mid-September) and non-use in enclosures over a 3-year period. Unfortunately, a season-long grazing treatment was not part of the study. Late-season use resulted in utilization of Kentucky bluegrass of 55 to 79 percent on dry meadows and 67 to 78 percent on moist meadows. Production on meadow types fluctuated over the years, but there was a significant increase in yield on the ungrazed areas. This increase in production was due to higher yield by sedges.

Kauffman concluded that some of the negative effects of grazing occurred because the moist and dry meadows were most heavily grazed during the late-use period. Some of the positive effects of late-season use included minimal compaction of the soil which was drier than in early summer, maintenance of plant vigor because of high carbohydrate reserves at time of grazing, and higher nutritive value of forage than on upland sites.

Several studies that have appeared in abstracts are probably nearing completion. These, I hope, will provide additional quantitative information for the management of meadow communities. Until more data are available, management actions for meadow communities can only be based on what we know now, together with a large amount of professional judgement.

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Section 3. Species Recommended for Major Plant Communities

SPECIES ADAPTED FOR SEEDING MOUNTAIN BRUSH, BIG, BLACK, AND LOW SAGEBRUSH, AND PINYON-JUNIPER COMMUNITIES

Richard Stevens

ABSTRACT: Successful range improvement depends on the seeding of plants adapted to a specific site and for which ample seed is available. This paper lists species adapted to mountain brush, big, black, and low sagebrush, and pinyon-juniper communities.

VEGETATIVE TYPES

A successful range improvement project begins with the selection of plants adapted to the sites being treated. Selected plants must be able to establish and maintain themselves over the years. Best results have been obtained where the species planted were adapted to the site rather than where a plant was expected to adapt to a site or where a site was treated to try to accommodate a particular species.

Many species are adapted to most sites, but seed availability can limit the number of species actually seeded. Only those species (tables 1 and 2) for which seed is commercially available are recommended. For some recommended species seed is plentiful; for some species seed is scarce.

Edaphic and climatic conditions usually vary within any specific vegetative type. Species recommended for seeding are adapted for each listed vegetative type. Each recommended species most likely will not be adapted at all local edaphic and climatic conditions within a specific vegetation type.

Individual site characteristics and requirements, seed availability, and project objectives will determine which species are selected.

Mountain brush type

Within the mountain brush type annual precipitation can range from 15 to 26 inches (38 to 66 cm). There are four general categories in the mountain brush type (species adapted to each are listed in table 1):

1. Thick stands of large and small Gambel oak (*Quercus gambelii*) and bigtooth maple (*Acer grandidentatum*) that are generally impenetrable and unavailable to livestock and big game. Herbaceous understory production is generally low. Forage production potential for the site is generally excellent.

2. Areas with scattered, small stands of serviceberry (*Amelanchier alnifolia*), Gambel oak, and mountain big sagebrush (*Artemisia tridentata vaseyana*). Productivity potential is generally good.

3. North and east exposures with good shrub variety and density. Temperatures are relatively cool and soil moisture is excellent. Forage production potential is generally high.

4. South and west exposures that are sunny and dry. Soils are generally shallow; forage production in the interspaces between shrubs is generally low; potential for improving forage production is the lowest within the mountain brush type.

Sagebrush types

1. Mountain big sagebrush (*A. tridentata vaseyana*). This type is generally found elevationally above basin big sagebrush (*A. tridentata tridentata*), from foothills up to timberlines. Precipitation varies between 12 to 30 inches (30 to 76 cm). Soils are generally deep, with good water-holding capacity. Because of the great variation in climatic and edaphic conditions that occur throughout this subspecies' range of occurrence, species recommended for seeding are broken into two groups: (a) those for areas that receive between 12 to 17 inches (30 to 43 cm) of annual precipitation; and (b) those for areas that receive over 17 inches (table 2). A large number of grasses, forbs, and other shrubs can be found growing in association with mountain big sagebrush.

2. Basin big sagebrush (*A. tridentata tridentata*). Basin big sagebrush is found on well-drained, deep soils on plains, in valleys, canyon bottoms, and foothills that receive 9 to 16 inches (23 to 41 cm) of annual precipitation. A majority of the irrigated farmlands, dry farms, and dry pastures within the Intermountain West were once inhabited by this subspecies.

A considerable number of forbs, grasses, and shrubs grow in association with basin big sagebrush. Species adapted to basin big sagebrush areas can be broken up into two groups: those that have potential with less than 13 inches (33 cm) of precipitation; and those that are adapted to areas receiving over 13 inches (table 2).

3. Wyoming big sagebrush (*A. tridentata wyomingensis*). Soils in which Wyoming big sagebrush occur are usually shallow, gravelly to stony, with low water-holding capacity. Annual precipitaiton varies from 7 to 15 inches (18 to

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Richard Stevens is Wildlife Biologist at the Great Basin Experimental Area, Utah Division of Wildlife Resources, Ephraim, Utah.

Table 1. -- Species adapted to the mountain brush types in the Intermountain West

Species		Exposure: North and East	Exposure: Southwest (Sunny & dry).	Community type: Open (Oak and serviceberry)	Community type: Closed (Oak and maple)
GRASSES AND FORBS:					
Brome, Regar	*Bromus biebersteinii*	X	X	X	
Brome, smooth (southern)	*Bromus inermis*	X	X	X	X
Fescue, hard sheep	*Festuca ovina duriuscula*	X	X	X	
Needlegrass, green	*Stipa viridula*	X	X	X	
Oatgrass, tall	*Arrhenatherum elatius*	X			X
Orchardgrass	*Dactylis glomerata*	X	X	X	X
Wheatgrass, bluebunch	*Agropyron spicatum*		X	X	X
Wheatgrass, crested	*Agropyron desertorum*		X		
Wheatgrass, fairway	*Agropyron cristatum*		X		
Wheatgrass, intermediate	*Agropyron intermedium*		X	X	
Wildrye, Great Basin	*Elymus cinereus*	X		X	
Wildrye, Russian	*Elymus junceus*		X		
Bluegrass, Kentucky	*Poa pratensis*				X
Alfalfa (Nomad, Ladak, Rambler), spreading strains	*Medicago sativa*	X	X	X	X
Balsamroot, arrowleaf	*Balsamorhiza sagittata*	X	X	X	
Balsamroot, curlleaf	*Balsamorhiza macrophylla*		X	X	
Burnet, small	*Sanguisorba minor*	X	X	X	
Crownvetch	*Coronilla varia*	X		X	X
Flax, Lewis	*Linum lewisii*	X	X	X	
Goldeneye, showy	*Viguiera multiflora*	X	X	X	X
Lomatium, Nuttall	*Lomatium nuttallii*		X	X	
Lupine, silky	*Lupinus sericeus*	X		X	X
Milkvetch, chickpea	*Astragalus cicer*	X	X	X	X
Penstemon, low	*Penstemon humilus*		X	X	
Penstemon, Palmer	*Penstemon palmerii*		X	X	
Penstemon, Rocky Mountain	*Penstemon strictus*		X	X	
Sainfoin	*Onobrychis viciaefolia*	X	X	X	
Sweetanise	*Osmorhiza occidentalis*	X			
Sweetclover, yellow	*Melilotus officinalis*	X	X	X	
Sweetvetch, Utah	*Hedysarum boreale utahensis*	X	X	X	
Sunflower, oneflower	*Helianthella annus*	X	X	X	
SHRUBS:					
Bitterbrush, antelope	*Purshia tridentata*		X	X	
Chokecherry, black	*Prunus virginiana melanocarpa*	X		X	
Elder, blueberry	*Sambucus cerulea*	X	X	X	
Ephedra, green	*Ephedra viridis*		X	X	
Mountain mahogany, curlleaf	*Cercocarpus ledifolius ledifolius*		X		
Mountain mahogany, true	*Cercocarpus montanus*	X	X	X	
Rabbitbrush, mountain rubber	*Chrysothamnus nauseosus salicifolius*	X	X	X	
Sagebrush, big mountain	*Artemisia tridentata vaseyana*	X	X	X	
Serviceberry, Saskatoon	*Amelanchier alnifolia*	X	X	X	
Serviceberry, Utah	*Amelanchier utahensis*		X	X	
Sqawapple	*Peraphyllum ramosissimum*	X	X	X	

38 cm). Generally, few herbaceous species are found growing in association with Wyoming big sagebrush. Likewise, few species are adapted for which seed is available (table 2).

4. Black sagebrush (*A. nova*). Annual precipitation throughout the area in which black sagebrush occurs varies between 7 and 18 inches (18 and 46 cm). Soils are generally shallow, rocky, and well drained, with poor moisture-holding capacity. Few grasses, forbs or shrubs for which seed is available are adapted to areas in which black sagebrush is dominant (table 2).

5. Low sagebrush (*A. arbuscula*). Low sagebrush grows on dry, sterile, rocky, often alkaline soils that range from shallow to moderately deep. Hardpans, 10 to 15 inches (25 to 38 cm) deep are

Table 2. -- Species adapted to sagebrush communities in the Intermountain West.

Species	Mountain big sagebrush (12-17)	(17+)	Basin big sagebrush (9-13)	(13+)	Wyoming sagebrush	Black sagebrush	Low sagebrush
	Inches [1]		Inches [1]				
GRASSES:							
Alkali sacaton, <u>Sporobolus airoides</u>			X		X	X	X
Regar brome, <u>Bromus biebersteinii</u>		X					
Smooth brome, <u>Bromus inermis</u> (southern)	X	X		X			
Hard sheep fescue, <u>Festuca ovina duriuscula</u>	X	X	X	X			
Sulcate sheep fescue, <u>Festuca ovina sulcata</u>	X	X	X	X			
Needle-and-thread, <u>Stipa comata</u>					X	X	X
Tall oatgrass, <u>Arrhenatherum elatius</u>		X					
Orchardgrass, <u>Dactylis glomerta</u>		X					
Indian ricegrass, <u>Oryzopsis hymenoides</u>	X		X	X	X	X	X
Bottlebrush squirreltail, <u>Sitanion hystrix</u>			X		X	X	X
Bluebunch wheatgrass, <u>Agropyron spicatum</u>	X		X	X	X	X	X
Bluebunch, beardless wheatgrass, <u>Agropyron inerme</u>	X		X	X	X	X	X
Crested wheatgrass, <u>Agropyron desertorum</u>	X		X	X	X	X	X
Fairway wheatgrass, <u>Agropyron cristatum</u>	X		X	X	X	X	X
Intermediate wheatgrass, <u>Agropyron intermedium</u>	X	X	X	X			
Pubescent wheatgrass, <u>Agropyron trichophorum</u>	X	X	X	X	X	X	X
Siberian wheatgrass, <u>Agropyron sibiricum</u>			X		X	X	X
Slender wheatgrass, <u>Agropyron trachycaulum</u>		X					
Tall wheatgrass, <u>Agropyron elongatum</u>		X					
Thickspike wheatgrass, <u>Agropyron dasystachyum</u>	X	X	X	X			
Great Basin wildrye, <u>Elymus cinereus</u>	X	X	X	X			
Russian wildrye, <u>Elymus junceus</u>	X		X	X	X	X	X
FORBS:							
Ladak, Nomad, spreading strains-Alfalfa <u>Medicago sativa</u>	X	X	X	X	X[2]		X
Arrowleaf balsamroot, <u>Balsamorhiza sagittata</u>	X	X		X			
Cutleaf balsamroot, <u>Balsamorhiza macrophylla</u>	X	X		X			
Small burnet, <u>Sanguisorba minor</u>	X	X	X	X	X[2]		
Crownvetch, <u>Coronilla varia</u>		X					
Lewis flax, <u>Linum lewisii</u>	X	X	X	X	X[2]		
Showy goldeneye, <u>Viguiera multiflora</u>	X	X		X			
Gooseberryleaf globemallow, <u>Sphaeralcea grossulariaefolia</u>			X		X	X	X
Scarlet globemallow, <u>Sphaeralcea coccinea</u>			X		X	X	X
Nuttall lomatium, <u>Lomatium nuttallii</u>		X					
Mountain lupine, <u>Lupinus alpestris</u>		X					
Silky lupine, <u>Lupinus sericeus</u>		X					
Silvery lupine, <u>Lupinus argenteus</u>		X					
Chickpea milkvetch, <u>Astragalus cicer</u>	X	X		X			
Low penstemon, <u>Penstemon humilus</u>	X	X		X			
Palmer penstemon, <u>Penstemon palmeri</u>	X	X	X	X	X	X	X
Rocky Mountain penstemon, <u>Penstemon strictus</u>	X	X	X	X			
Sainfoin, <u>Onobrychis viciaefolia</u>	X	X		X			
Sweetanise, <u>Osmorhiza occidentalis</u>		X					
Yellow sweetclover, <u>Melilotus officinalis</u>	X	X	X	X	X[2]	X[2]	X[2]
Utah sweetvetch, <u>Hedysarum boreale utahensis</u>	X	X	X	X			
Oneflower sunflower, <u>Helianthella annus</u>	X	X	X	X			

(con.)

Table 2. -- (con.)

Species	Mountain big sagebrush (12-17)	(17+)	Basin big sagebrush (9-13)	(13+)	Wyoming sagebrush	Black sagebrush	Low sagebrush
	Inches[1]		Inches[1]				
SHRUBS:							
Antelope bitterbrush, *Purshia tridentata*	X	X	X[2]	X	X[2]		
Black chokecherry, *Prunus virginiana melanocarpa*		X					
Stansbury cliffrose, *Cowania mexicana stansburiana*	X	X	X	X			
Blueberry elder, *Sambucus cerulea*		X					
Green ephedra, *Ephedra viridis*	X		X	X	X[2]		
Nevada ephedra, *Ephedra nevadensis*			X		X	X	X
Prostrate kochia, *Kochia prostrata*	X		X	X	X	X	X
True mountain mahogany, *Cercocarpus montanus*	X	X		X			
Curlleaf mountain mahogany, *Cercocarpus ledifolius*	X	X		X			
Hairy low rabbitbrush, *Chrysothamnus viscidiflorus puberulus*	X		X	X	X	X	X
Mountain rabbitbrush, *Chrysothamnus viscidiflorus lanceolatus*		X	X	X	X		
Mountain rubber rabbitbrush, *Chrysothamnus nauseosus salicifolius*		X					
White rubber rabbitbrush, *Chrysothamnus nauseosus albicaulis*	X	X	X	X			
Basin big sagebrush, *Artemisia tridentata tridentata*	X		X	X			
Mountain big sagebrush, *Artemisia tridentata vaseyana*	X	X					
Wyoming big sagebrush, *Artemisia tridentata wyomingensis*					X		
Black sagebrush, *Artemisia nova*					X	X	
Low sagebrush, *Artemisia arbuscula*							X
Fourwing saltbush, *Atriplex canescens*	X		X	X	X	X	X
Saskatoon serviceberry, *Amelanchier alnifolia*	X	X					
Winterfat, *Ceratoides lanata*	X		X	X	X	X	X

[1]Annual precipitation.
[2]With more than 12 inches (30 cm) annual precipitation.

not uncommon. Annual precipitation varies between 7 and 18 inches (18 and 46 cm).

Pinyon-Juniper Type

This type is widespread throughout the Intermountain West. Pinyon or juniper (or both) can be found in all sagebrush types. Where pinyon or juniper is dominant, sagebrush can be found in small or large quantities.

The species adapted to a particular pinyon-juniper site are indicated by the sagebrush present. Species adapted to the sagebrush type (table 2) associated with the pinyon-juniper should be adapted to the site.

PLANTS FOR REVEGETATION OF RIPARIAN SITES WITHIN THE INTERMOUNTAIN REGION

Stephen B. Monsen

ABSTRACT: Revegetating riparian zones is frequently difficult because many sites have been seriously altered and reconstruction of the entire plant community may be required. Seedbed preparation and planting are frequently delayed by spring flooding. Techniques must be employed to minimize streambank erosion. Species recommended for planting riparian habitats are discussed.

INTRODUCTION

Restoration of riparian sites is a major concern in the management of range and wildlife habitats throughout the Intermountain region. Many riparian zones have been seriously degraded resulting in the loss of habitat for aquatic and terrestrial animals (Boussu 1954; Johnson and others 1977). Although improvement of many western rangelands has occurred through management and revegetation programs, many riparian habitats have responded slowly to such treatments (Meehan and Platts 1978).

Grazing by livestock has had the most destructive effect upon riparian vegetation (Behnke 1977). Removal of streamside vegetation has resulted in destabilization of the stream channel and streambanks. Stabilization and improvement of riparian habitats is essential to the overall management of adjacent rangeland and associated watersheds. Sites that are not totally degraded usually can be restored through livestock management and natural or artificial revegetation. Platts (1981) reports that improvement in density and vigor of riparian vegetation occurs as livestock grazing is regulated. Carlson (1976), Edminister (1919), and Fowler and Hammer (1976) found that plantings of adapted species have been successful in improving certain riparian areas.

Values of Riparian Habitats

Within the Intermountain region, riparian vegetation is most often found along meandering streams in narrow strips that may be only a few feet wide. Wet and semiwet meadows also intermix through the flood plain. Riparian habitats benefit from the additional water provided by the stream and, thus, the composition and growth of the vegetation differs from that found on adjacent uplands. A greater variety of plants is encountered within the riparian zone than on adjacent drier sites. This normally includes a mixture of woody and herbaceous species. Abundant succulent herbage is produced throughout most of the growing season. Grazing animals are attracted to the water, shade, and forage provided by these sites, particularly during mid- and late summer when other vegetation is dry. The sites not only furnish forage and water but also concealment and protection. Fish and aquatic life are dependent upon the vegetation to provide site stability and food.

Planting Conditions in Riparian Habitats

Within the Intermountain region, most riparian zones requiring revegetation have been seriously altered. Appropriate revegetation practices must be used to stabilize and improve the sites. The most obvious conditions that influence restoration measures are:

1. Vegetative protection is required to control soil erosion and streambank deterioration. Often entire watersheds have been seriously altered and the entire area must be restored to reduce serious flooding and sedimentation of the riparian zone. Restoration along the stream normally requires the reestablishment of woody and herbaceous plants. Shrubs and trees often are the most important part of the plant community. Woody vegetation provides stability to the sites but usually requires a number of years to develop.

2. Sites requiring restoration are often inaccessible to mechanical equipment. The route of many streams extends along narrow, steep, and rough terrain. Only small areas may be level enough to accommodate vehicles or planting machinery. Equipment designed to treat small areas is not always available nor adequate. Consequently, in many situations it is impractical to mechanically prepare or plant the disturbed areas.

3. Most riparian zones requiring treatment traverse a number of different plant communities and site conditions. The riparian vegetation may change abruptly and frequently. Restoration of the vegetation may require reestablishment of many species of adapted plants. Plantings

Stephen B. Monsen is a Botanist/Biologist at the Forestry Sciences Laboratory, USDA Forest Service, Intermountain Forest and Range Experiment Station, Boise, Idaho.

can become quite complex. Variation in planting sites can normally be accommodated by seeding mixtures. However, if transplant stock is used, areas must be correctly categorized and planted with adapted species.

4. Problem sites are often seriously disturbed and altered. The riparian zone frequently has lost much of the original vegetation and serious cutting and erosion may have occurred. Thus, the topsoil is lost, the water table lowered, and active erosion continues, all interfering with the establishment of small plants. The sites no longer may be able to support the original or desired vegetation. Intensive treatment is required to prepare and maintain a suitable seedbed, and introduced species may be required.

5. Noxious weeds and highly competitive rhizomatous plants often invade and occupy riparian zones and interfere with the establishment of more desirable plants. Some of the most serious weeds invade along streambanks and can spread quickly, infesting large areas. The weedy plants must be removed prior to seeding or transplanting without causing further destruction to the streambank. Consequently, control by plowing or disking is not always feasible. Many sites support a desirable understory of herbs, yet may lack a suitable overstory of shrubs and trees. To establish woody plants, competition from the herbs must be reduced.

6. Exclusion of grazing animals from the treated areas is often difficult. Animals naturally concentrate along the riparian zone and can seriously damage new plantings. Without satisfactory control of livestock, new seedlings and immature plants could be vulnerable to grazing for a number of years.

7. Planting is often delayed past the optimum season by flooding and high runoff. Appropriate planting seasons cannot always be selected because of fluctuating water levels. Certain sites cannot be fall seeded because high runoff and flooding in the spring washes away or inundates seeds and new seedlings. If seeding or transplanting is delayed until summer when flooding has receded, the work must be completed quickly before the soils dry. Usually the planting sites vary in regard to flooding and availability of soil moisture. Some sites become dry and ready for planting while adjacent areas remain under water.

METHODS OF TREATMENT

Site Stability

Stability of the streambank and the seedbed must be considered as riparian sites are prepared for planting. New seedlings cannot become established amid a competitive stand of weeds or perennial plants. Thus, sites are often plowed, disked, or otherwise treated to reduce existing competition. These practices can seriously diminish the stability of the streambank, permitting excessive erosion, and should be avoided if alternative treatments are possible. Seedbed preparation practices and weed control treatments that do not destroy or seriously decrease streambank stability must be selected. Unstable areas should be mulched or protected using control structures or grading. Sites supporting a residual number of desirable plants should be protected and allowed to recover. Interseeding or seeding of small disturbed areas intermixed throughout such sites should be considered.

Weed Control

Control of noxious weeds is often required prior to planting. Sites supporting perennial weeds such as Canada thistle (*Cirsium arvense*), or whitetop (*Cardaria draba*), should be mechanically or chemically treated. Herbicides are effective but contamination of the stream must be avoided. Many sites support little vegetation and seeding can be accomplished without weed control.

Seeding

Areas not subjected to flooding should be fall planted. Spring plantings are acceptable in regions where spring or summer precipitation could start germination and sustain new plants. Where flooding occurs, planting should be done as soon as possible after the water recedes. Where possible, drill seeding or planting using a cultipacker is recommended. Broadcast seeding is acceptable if the planted areas can then be harrowed or the seeds covered using a drag or similar equipment. Seedbeds dry quickly even in riparian communities. Although the water table may occur close to the soil surface, the moisture is not usually available to newly germinated seedlings. Losses of the young plants may often occur as the surface dries.

Transplanting

Transplanting is the most practical means of establishing shrubs and trees. Although most riparian sites receive supplemental ground water, not all areas remain wet enough to assure the establishment of newly transplanted stock. Establishment of the transplant is the most critical hurdle to overcome in revegetation. Once plants become established, the roots are usually able to grow into the wet soil and growth is accelerated.

Planting unrooted cuttings is often attempted. Success is variable, depending upon the condition of the cutting and the planting site. Rooted cuttings and nursery or container grown stock are recommended. Cuttings can be rooted in a nursery bed or under greenhouse conditions.

Willow (Salix) or poplar (Populus) cuttings are better able to establish if planted as rooted stock. When planted, all stock should be dormant and in good condition.

Transplant stock should not be planted directly into established stands of understory competition. Weedy vegetation should be removed by scalping or herbicide application. Using a hand sprayer to treat a spot about 30 inches (76 cm) in diameter with a herbicide is sufficient to eliminate competition and facilitate transplanting. Adding an agricultural dye to the herbicide solution marks the spray area and aids in relocating the planting spots. "Roundup" has been successfully used to control grasses, sedges, and broadleaf herbs. The herbicide must be sprayed on actively growing vegetation. The transplant should not be planted in the sprayed area until the solution has dried.

Most transplanting failures result from improper handling of stock and planting practices. Container stock should be hardened before field planting. Plantings that are delayed until late in the spring are not only subjected to drying soil conditions, but desiccation from high temperatures.

Site Improvement by Management

Many riparian sites support a remnant of woody and herbaceous plants. Although the plants may be heavily browsed and weak, recovery can occur if grazing is controlled. Reestablishment of beaver and moderation of streamflow also benefit plant recovery (Smith 1980). Not all sites are capable of recovering in an acceptable period even when protected; therefore, planting may be required.

Recommended Species

Plants recommended for riparian communities normally consist of the native species prevalent in the area. Many woody species that are encountered in the riparian zones can be propagated by stem or root cuttings. If not, seeds can be collected and plants can be grown in containers or as bareroot nursery stock. Species recommended for planting riparian zones in the major plant communities of the Intermountain region are listed in tables 1 and 2.

Most planting stock should be of sufficient size to survive the harsh conditions that often occur. Usually large size plants, 2-0 nursery stock or 18 to 20 inch (45 to 50 cm) container-grown plants survive better than smaller stock. Plants should have a satisfactory root system to be able to grow quickly and become fully established. Most transplant stock can be nursery grown within one or two seasons, as shown in table 3.

Most species can also be grown as container stock, but production and field planting costs are increased. Species that are easily propagated by stem or root cuttings can be grown with little cost. When only a few plants are required, cuttings are a quick and satisfactory means of propagation. Small seedlings or young plants can often be dug from the area and used in restoration projects. Regardless of the stock used, all materials should be healthy and in good condition for planting. Failure to use suitable stock cannot be justified.

Plummer and others (1968) report the success of certain species for inland saltgrass sites. McGinnis and others (1963) and Eckert (1975) describe plants for wet meadow situations. Many plants that normally are easy to propagate such as willow (Salix), Dogwood (Cornus), and cottonwood (Populus) may not survive when planted on disturbed areas. Even when adapted species are used, considerable care is required to assure planting success.

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Table 1.--Grasses and broadleaf herbs recommended for riparian plantings within major plant communities

Species	Areas of adaptation: Wet meadow	Forest types	Mountain brush	Sagebrush and desert shrubs	Salt-grass
Grasses					
Barley, meadow	x	x			
Bluegrass, Kentucky	x	x	x		
Bluegrass, Sandberg		x	x	x	x
Brome, meadow		x			
Brome, mountain		x			
Brome, smooth	x	x	x		
Canarygrass, reed	x	x			x
Fescue, tall		x	x	x	x
Foxtail, meadow	x	x	x		x
Hairgrass, tufted	x				
Orchardgrass		x	x		
Redtop	x	x	x	x	x
Reedgrass, chee	x	x			
Ryegrass, perennial	x	x			
Sacaton, alkali					x
Squirreltail, bottlebrush			x	x	x
Timothy	x	x	x		
Wheatgrass, bluestem		x	x		
Wheatgrass, slender		x			
Wheatgrass, streambank			x	x	
Wheatgrass, tall			x	x	x
Wildrye, creeping	x		x	x	x
Wildrye, Great Basin	x		x	x	x
Wildrye, mammoth					x
Wildrye, Russian			x	x	x
Forbs					
Alfalfa, creeping type		x	x	x	x
Aster, alpine leafy-bract	x	x	x		
Aster, Pacific	x		x	x	x
Bassia, fivehook				x	x
Clover, alsike	x				
Clover, strawberry	x				x
Cowparsnip, common	x	x			
Crownvetch		x	x		
Medick, black		x	x	x	x
Milkvetch, chickpea		x	x	x	
Valerian, edible	x	x	x		
Yarrow		x	x	x	
Sagebrush, Louisiana		x	x	x	

Table 2.--Trees and shrubs recommended for planting riparian sites within major plant communities

Species	Areas of adaptation				
	Wet meadow	Forest types	Mountain brush	Sagebrush and desert shrubs	Salt-grass
Alder, thinleaf	x	x			
Aspen, quaking	x	x			
Birch, western river	x	x			
Buckthorn	x	x	x		
Buffaloberry, russet		x	x		
Buffaloberry, silver	x		x		x
Ceanothus, redstem	x	x			
Chokecherry, black	x	x	x		
Cinquefoil, bush	x	x			
Currant	x	x	x	x	
Dogwood, redosier	x	x	x		
Elaeagnus, autumn	x	x	x		
Elder, blueberry			x	x	
Elder, redberry		x	x		
Greasewood, black				x	x
Hawthorn		x	x	x	
Honeysuckle, Tatarian			x	x	
Honeysuckle, Utah	x	x			
Maple, bigtooth		x	x		
Mountain-ash, Greenes	x	x	x		
Ninebark, mallow	x	x	x		
Pachistima, myrtle	x	x			
Peachbrush, desert				x	x
Pine, lodgepole	x	x			
Plum, American			x		
Poplar, black			x	x	x
Poplar, narrowleaf			x	x	x
Raspberry	x	x			
Rose, Woods	x	x	x		
Russian-olive			x	x	x
Sagebrush, silver			x	x	
Saltbush, Gardner				x	x
Snowberry, mountain	x	x	x	x	
Snowberry, western	x	x			
Willow, purpleosier		x	x	x	
Willow, Scouler		x			

Table 3.--Size and type of planting stock recommended for field transplanting

Species	Transplant material			
	Nursery stock	Containers	Cuttings	Wildings
Alder, thinleaf	1-0	x		
Aspen, quaking	2-0	x	stem/roots	
Birch, Western river	1-0	x	roots	
Buckthorn	1-0	x	stem	
Buffaloberry, russet	1-0	x	roots	
Buffaloberry, silver	2-0	x	roots	
Chokecherry, black	2-0	x	stem/roots	
Cinquefoil, bush	1-0	x	roots	
Currant	2-0	x	stem/roots	
Dogwood, redosier	1-0	x	stem/roots	
Elaeagnus, autumn	2-0	x	stem/roots	
Elder, blueberry	1-0	x	roots	
Elder, redberry	1-0	x	roots	
Greasewood, black	2-0		stem/roots	
Hawthorn	1-0		stem	
Honeysuckle, tatarian	1-0	x	stem	
Honeysuckle, Utah	1-0	x	stem	
Maple, bigtooth	2-0	x		
Mountain-ash, Greenes	2-0	x	roots	
Ninebark	2-0	x	stem/roots	
Pachistima, myrtle	2-0	x	roots	
Peachbrush, desert	2-0	x		
Pine, lodgepole	2-0	x		
Plum, American	1-0	x	stem/roots	
Poplar, black	1-0	x	stem	
Poplar, narrowleaf	1-0	x	stem	
Raspberry			stem/roots	
Rose, Woods	1-0	x	stem/roots	
Russian-olive	1-0	x	stem/roots	
Sagebrush, silver	1-0	x		x
Saltbush, Gardner	2-0	x	stem/roots	x
Snowberry, mountain	1-0	x	stem/roots	x
Snowberry, western	1-0	x	stem/roots	x
Willow, purpleosier			stem	
Willow, Scouler			stem	

CHARACTERISTICS AND USES OF IMPORTANT GRASSES FOR ARID WESTERN RANGELANDS

John M. Sours

ABSTRACT: Twenty-five species/varieties of native and introduced grasses are described with characteristics, origin, and suggested uses. Factors affecting seed production, distribution, and availability are discussed emphasizing specifications for seed procurement, seed availability, varietal characteristics, and comparative seed costs.

INTRODUCTION

The many varieties of grasses and forbs now commercially available are the result of extensive research, and represent an incalculable expenditure of time and money. The major source of improved germ plasm for rangeland use has been USDA Soil Conservation Service Plant Material Centers. Several varieties have also originated from State Agricultural Experiment Stations. Other varieties now in widespread use were developed by Agriculture Canada Research Stations.

The Intermountain Forest and Range Experiment Station is a very promising source of native grasses, shrubs, and forbs for arid lands. Several commercial seed producers in the Intermountain West are impatient for the release of the Station's promising ecotypes. It is frustrating for the seed industry to receive repeated solicitations for certain species, and respond with poor second or third choices. A great deal of research has been completed, and promising ecotypes have been isolated. Demand for this germ plasm has been established; supply must be expedited. The commercial seed industry may gradually become active in research and development of improved germ plasm of arid land ecotypes.

GRASS SPECIES AND VARIETIES

The seed industry tends to simplify the solution to poor range quality. A stock answer to low production is another reseeding program using species with high forage potential. A small expenditure for seed, and lush meadows supposedly appear as if by magic. Livestock and wildlife flourish; clear sparkling streams flow freely; living becomes easy.

Ever so slowly, we learn that it takes more than just seed. The science of range management grows constantly, reminding us of how little we know. Debates rage on as to the benefits of one management system over another. We seem to have a solution, something unexpected happens, and the search starts over again.

John M. Sours is a member of the Intermountain Grass Growers Association, Post Falls, Idaho.

Nevertheless, a seeding program, with good technology, can greatly accelerate the overall program to increase the productivity and diversity of rangelands. The pristine climax vegetation of the early 1800's may not be achievable after several generations of abuse, but improvement is indeed possible. An integral part of this "good technology" is the procurement of high-quality seed of the most promising species and, to a lesser extent, the selection of the most promising varieties within the species. The following section describes several species suited to rangeland plantings.

1. Crested wheatgrasses, the "golden grasses of the West", require at least 10 inches (25 cm) of coarse-to-medium-textured soils and 6 to 15 inches (15 to 38 cm) annual precipitation. Development will be slow in the more arid range areas, and new seedings may need to be protected from grazing for at least 2 years. They establish well when planted on a firm seedbed. Seeds should be drilled about 0.5 inches (1 cm) deep. The cresteds have performed well in monocultures, or when seeded with alfalfa. Consequently, land managers are reluctant to diversify plantings to include other species. (a) Standard crested wheatgrass (Agropyron desertorum), the old-timer, dating back to early introductions has all but disappeared. A tendency, in some circles, is to bag up all unidentified, untraceable, crested wheatgrass seed and call it "standard." I prefer the terminology of "crested wheatgrass, variety not stated", for unidentified seed. Many useful seed lots are available for the "non-purist" who wants all the seed his money can buy. (b) 'Nordan' crested wheatgrass (A. desertorum) is a perennial, drought-tolerant bunchgrass. It is an outstanding grass for spring grazing or hay, and very persistent and palatable to sheep, cattle, and horses. (c) Fairway crested wheatgrass (A. cristatum) is similar to Nordan in many characteristics; however, it is a little shorter and finer stemmed. It matures a little earlier and has a higher leaf-to-stem ratio. It is weakly rhizomatous and looks "turfier". (d) 'Ruff' dwarf crested wheatgrass (A. cristatum) closely resembles fairway. It hasn't caught on well for rangeland seeding, and most seed production has been plowed out due to lack of interest.

2. Thickspike wheatgrass (A. dasystachyum) is a widely occurring, native, sod-forming grass. It is best adapted to the northern Intermountain West and the drier areas of the Pacific Northwest. It resembles western wheatgrass (A. smithii), but is more drought tolerant. It is also similar to streambank

wheatgrass (A. riparium). This whole complex may cross under field conditions.

Thickspike occurs on sand, sandy loam, and loam soils, yet is often successfully used to reclaim rocky sites. It requires from 8 to 15 inches (20 to 41 cm) of annual precipitation. Thickspike provides good forage in spring and summer, but must be protected from overgrazing. It is palatable to livestock, deer, and rabbits. It may be the only nesting cover for birds in sandy areas. Native stands are found in communities with Indian ricegrass, sand dropseed, and needlegrass. (a) 'Critana' is the most common cultivar and has enjoyed great popularity. It is used as the basic component of many reclamation seedings. It does have a serious seed production problem. The purest foundation seed may yield a mixture of thickspike and slender wheatgrass in the first generation. The problem was easily overcome, however, by simply changing the seed certification standards to allow 30 percent slender wheatgrass in thickspike and still carry the cherished "blue tag" of "pure" certified seed. (b) 'Elbee' is a variety of thickspike released 3 years ago by Agriculture Canada. It appeared to be a pure thickspike strain; however, in 1981 plantings "blew up" as slender wheatgrass variants appeared.

3. Tall wheatgrass (A. elongatum) is a tall, late maturing, perennial bunchgrass. It is vigorous enough to outgrow recurring deposits of wind-borne volcanic ash on the subirrigated canyon floors of the central Washington scabland. Although coarse, it is surprisingly palatable and can be used to extend grazing seasons well into the summer. It can also be used for silage or chopped hay. Tall wheatgrass does not perform well on poorly drained soils, but thrives where irrigated or subirrigated. Its most outstanding characteristic is its tolerance to saline, saline-alkali, or alkali soils, or to water containing these salts.

Tall wheatgrass is used on large commercial livestock pastures in Texas where irrigation water has become too alkaline for other forage. Forage utilization requires special management. (a) 'Alkar' is the most common variety in the northern latitudes. (b) 'Jose' is a new variety that is doing well in the southern States.

4. Bluebunch wheatgrass (A. spicatum) is a long-lived perennial bunchgrass with wide adaptability. It occurs in native stands from the mountainous foothills associated with Ponderosa pine or Douglas fir, to open prairies with Idaho fescue and Sandberg bluegrass. It also is found with needlegrass in drier areas with sagebrush and rabbitbrush. Bluebunch requires from 6 to 35 inches (15 to 89 cm) of annual precipitation and is found from elevations of 300 to 5,000 ft (91 to 1 524 m). It occurs on both northern and southern slopes, depending on location. It requires at least 10 inches (25 cm) of medium to moderately coarse, sandy loam soils. It is not tolerant of excessive salts or soil moisture.

Elk, whitetail deer, mule deer, and antelope utilize bluebunch wheatgrass extensively throughout the winter and spring months. Bluebunch is an excellent range grass for sheep, cattle, and horses. Grazing management is critical with the bluebunches. Much of the native population has been destroyed by overgrazing. (a) 'Secar' is the only named variety that has been domesticated. It became commercially available in 1981. Supplies of seed are expected to increase substantially with crop harvest, and prices may become more reasonable by the fall of 1982. (b) Common bluebuch wheatgrass is harvested from one or two native stands each year. Although the mechanical quality of this seed is usually excellent, adaptability is unknown.

5. Beardless bluebunch wheatgrass (A. spicatum inerme) was previously classified as A. inerme. The only apparent taxonomic difference between bluebunch and beardless bluebunch is the presence or absence of awns on the seed. Both types have basically the same adaptation and use. (a) 'Whitmar' is the only named variety of beardless bluebunch that is commercially available. The importance of both varieties demands a dependable supply of seed at a more reasonable price than has been experienced in the past. Quality seed will probably never be as inexpensive as crested unless varieties or techniques can be developed to increase seed yield.

6. Intermediate wheatgrass (A. intermedium) is an introduced, perennial, sod-forming grass. It is a tall species that produces high yields of excellent hay or pasture grass. Intermediate is adapted to soils that are well drained and loamy to fine textured. It tolerates only mild alkalinity. It requires a minimum of 14 inches (36 cm) of precipitation except on deep, fine-textured soils where it performs well on only 12 inches (30 cm) of moisture. Intermediate germinates promptly and has excellent seedling vigor.

Mixtures of intermediate wheatgrass and dryland alfalfa are very compatible. They are adapted to similar sites and mature at about the same date. There are several varieties from which to choose: (a) 'Oahe' is the most abundant variety, because most seed growers feel that it yields the most seed per acre. (b) 'Greenar' is usually available at a premium price. It is reported to have an advantage over the other varieties in forage quality. (c) 'Amur' is a variety released in New Mexico. Its production is very limited. (d) 'Tegmar' is a dwarf variety about half as tall as Oahe and Greenar. It spreads by forming rhizomes and develops a dense sod more rapidly than the other intermediates. It produces quality forage, but is usually used for erosion control on industrial disturbances. It is excellent for sodded waterways because it withstands considerable siltation. Tegmar can be mowed closely to provide low-maintenance turf.

7. Pubescent wheatgrass (A. trichophorum) is an introduced species quite similar to

intermediate wheatgrass in characteristics and adaptability. It matures a week or more earlier than intermediate, and forms a denser sod. Like intermediate, it stays green well into summer if sufficient moisture is available. It is a little more drought tolerant than intermediate, being able to perform at 12 inches (30 cm) of moisture or even a little less at elevations over 3,500 ft (1 067 m). Also, like intermediate, pubescent forms a large root mass. The basic taxonomic difference between the two species is the presence of short, stiff hairs on the stem, leaves, and seeds of pubescent wheatgrass. Several varieties are usually available from which to makes a selection. (a) 'Mandan', a release derived from North Dakota, is used extensively in the northern Great Plains and performs very well over a wide area. (b) 'Greenleaf' is a Canadian selection developed at the Northern Great Plains Research Center in Mandan, North Dakota. It has a slightly greener color than Mandan and has excellent forage qualities. (c) 'Topar' is another excellent variety for forage and cover. It is often used on marginal sites as part of revegetation mixtures. (d) 'Luna' was selected at the Los Lunas Plant Material Center in New Mexico. It has proved capable of establishment on harsh sites. In the past several years, Topar and Luna have commanded a premium seed price.

8. Streambank wheatgrass (A. riparium) is a native, sod-forming grass. It has tough, aggressive rhizomes that produce a durable sod for road shoulders, sod runways, parking lots, and dryland turf areas. It is not particularly palatable to livestock or wildlife, which enhances its use as permanent ground cover along highways. It requires about 12 inches (30 cm) precipitation at lower elevations and will maintain itself at 9 inches (23 cm) at elevations over 3,500 ft (1 067 m). It is highly competitive with weeds and brush under minimum moisture conditions. (a) 'Sodar' is the only variety of this species that has been selected and named.

9. Slender wheatgrass (A. trachycaulum) is another of the native bunchgrasses that is commercially available. Its outstanding characteristic is its rapid establishment in areas that receive 12 to 18 inches (30 to 46 cm) of precipitation. It is adapted to a wide variety of soils and tolerates moderate alkalinity. Slender wheatgrass is frequently found in mixed stands with western wheatgrass in lakebed overflow areas. The rapid establishment of slender wheatgrass makes it an excellent choice for inclusion in mixtures that contain slower starting species. Two varieties are usually available: (a) 'Revenue' is a Canadian variety produced in large volumes as certified seed in Canada. Only uncertified seed is produced in the United States. (b) 'Primar' is a SCS release that may be grown for certified seed in the United States. Primar has excellent adaptability to a wide area, but is not as readily available as the Canadian Revenue probably because Canadian seed periodically floods the U.S. Market.

10. Creeping meadow foxtail (Alopecurus arundinaceus) and meadow foxtail (A. pratensis) have similar characteristics and adaptability. Their outstanding feature is adaptability to poorly drained, strongly acid soils. Both are extremely winterhardy, even when covered with ice. They start growth early in the spring and show no damage from late frost. They mature early and recover rapidly from grazing or mowing. The seed is light and fluffy, thus hard to harvest, condition, and plant. It is also slow to become established.

The most significant difference between these two species is that meadow foxtail is essentially a bunchgrass, and creeping foxtail is rhizomatous. (a) 'Garrison' is a selection of the creeping species and is commercially available. (b) Meadow foxtail has no developed varieties, but is harvested from native stands.

11. Smooth brome (Bromus inermis) is an introduced sod-forming grass planted extensively for hay. It requires a relatively fertile, neutral soil, and at least 15 inches (38 cm) of precipitation, but it can withstand periods of drought. It is especially noted for high-quality hay when mixed with alfalfa.

Smooth brome is often categorized into three forms: southern, intermediate, and northern. These might also be called very aggressive sod forming, moderately sod forming, and midly sod forming. Many varieties of brome are now commercially available. One or two popular varieties of each type are worthy of mention: (a) Southern - 'Lincoln', 'Achenbach' (b) Intermediate - 'Manchar', 'Magna' (c) Northern - 'Polar', 'Carleton'.

Manchar is very popular in the West because it has good winter hardiness. Its moderate aggressiveness does not compete excessively with alfalfa.

12. Meadow brome (Bromus biebersteinii) is similar to smooth brome, but has a more basal leaf development, and recovers much more rapidly after cutting or grazing. It tolerates slightly acid soils and is used quite often with red clover or alsike clover. (a) 'Regar' is the only named variety of meadow brome. The rapid recovery of Regar makes it more suitable for grazing than smooth brome.

13. Mountain brome (B. marginatus) is a vigorous, rapidly establishing perennial bunchgrass. It is a native species from 1,500 to 4,500 ft (457 to 1 372 m) elevation from southern Alberta and British Columbia to New Mexico. Mountain brome requires from 16 to 30 inches (41 to 76 cm) of annual moisture. It develops a large root mass quite rapidly, and tolerates soils in the pH range of 5.5 to 8.0. Mountain brome is an excellent grass for pasture or hay. It is also a useful species for revegetating disturbed sites due to its rapid establishment and soil stabilizing capability. As it is a bunchgrass, it does not overcompete with other species in a mixture. (a) 'Bromar' is the only named variety of this

species. It was released by the Pullman Plant Materials Center in 1946. It was popular as a green manure crop for several years but fell into disfavor due to devastating attacks of loose smut in the seed production fields. Production ceased as yields approached zero. Recently, development of a chemical smut treatment has re-established a high quality seed supply for this unique species.

14. Indian ricegrass (Oryzopsis hymenoides) is a native bunchgrass widely distributed on droughty, sandy, rocky soils throughout the West. Its tremendous drought tolerance, winter nutritional value and palatability make it an important species for many types of wildlife and livestock. Several disadvantages have restricted its use. Seed collected in one area may not perform well in another area; specifically, when seed from low elevations in southern latitudes is brought north or to higher elevations. Seed can be mechanically harvested only in limited areas and hand harvested seed is high priced. Seed germination and seedling establishment are very slow. Seed must be planted deeply to sustain germination in droughty soils. If this starchy, high-energy seed is broadcast or planted very shallow, it will be eaten by birds and rodents long before it germinates.

At the present time, two named varieties have been released. (a) 'Nezpar' is an ecotype from north central Idaho that is now in substantial commercial, mechanized production. We can expect dependable supplies of this variety and a decrease in seed prices. This variety was developed by the SCS Plant Materials Center in Aberdeen, Idaho. (b) 'Paloma' is the other named variety and represents the more southern ecotypes. It was released by the SCS Plant Materials Center in Los Lunas, New Mexico and is progressing very well with the professional seed growers.

15. Mountain rye (Secale montanum) is a species that has become established and has persisted both in native stands and in cultivated seedings at mid-to-high elevations. It is a dependable perennial closely related to annual cereal rye. It should have great potential as a nurse crop for high-elevation mixtures, or for use as a monoculture in the rapid stabilization of critical areas. At this time there is no commercial supply or production. This species is worthy of an accelerated release program. The plant is well adapted to mine disturbances throughout a wide range of sites.

16. Bottlebrush squirreltail (Sitanion hystrix) is a native species that is becoming more available. It is a competitive perennial that can invade cheatgrass ranges. It produces excellent forage in the early spring for livestock and wildlife.

A major problem with squirreltail is that the seeds will not thresh or dislodge from the head or stem until the seed is completely ripe. When ripe, the entire head disarticulates. The seed is difficult to harvest with mechanized equipment. It is important that a strain be developed that can be combine harvested.

17. Canby bluegrass (Poa canbyi) is a native perennial bunchgrass. It is a short, understory grass that competes with cheatgrass on shallow soils. It grows vigorously in the early spring and during mild winter periods. It enters dormancy following seed set in the early summer. Canby bluegrass should be used to increase plant diversity, compete with cheatgrass, and provide ground cover under and around taller bunchgrasses, shrubs, and forbs. It is palatable to wildlife and livestock and is one of the earliest grasses to green up in the spring. (a) Currently 'Canbar' is the only named variety. Although it was released in 1979, it is just now becoming commercially available. Supplies should continue to improve.

18. Russian wildrye (Elymus junceus) is an introduced perennial bunchgrass. While classified as a cool season grass, it grows actively during mid-summer if moisture is available. The leaves are all basal and seed stalks are bare. Russian wildrye is slow to establish due to the low vigor of young seedlings. It remains palatable and digestible through the summer months, and complements any warm season grasses in the area. (a) 'Vinall' is the most prevalent variety currently on the market. Its foremost characteristic is the stabilization of seed yields. (b) 'Sawki' is a Canadian variety that has become difficult to purchase by variety name. It is reasonably safe to assume that most of the common seed on the market is of the Sawki germ plasm.

19. Great Basin wildrye (Elymus cinereus) is a native bunchgrass that once covered large areas of western North America. This species has unique adaptability to saline/alkaline lakebeds and also the surrounding uplands. It grows in communities with salt desert species, such as saltgrass, and also upland species such as wheatgrasses, rabbitbrush and sagebrush. It will not tolerate shallow soils, nor does it perform well on deep, coarse, sandy soils. It is adapted to a wide range of other soil types. It requires a minimum of 8 to 16 inches (20 to 41 cm) of annual precipitation. It will grow well on high water table areas, and responds well to irrigation. Spring grazing is extremely detrimental to basin wildrye. For this reason only remnants of the once vast native stands can be found.

Great Basin wildrye provides excellent cover and nesting for pheasants. Birds and rodents also eat the seeds. It is utilized by deer, primarily for bedding areas and cover, but they do browse it to a limited degree. (a) 'Magnar' is the only named variety. It was developed from a selection of Canadian origin by the SCS Plant Materials Center in Aberdeen, Idaho.

20. Altai wild ryegrass (Elymus angustus) was introduced from Siberia into Canada for testing in 1934. It was released to Canadian growers as the certified variety, 'Prairieland', in 1976. As with the other wildryes, Altai has an abundance of coarse basal leaves, which grow erect from the crown. The seed stalks are tall

and bare. This variety is adapted to deep soils. Its roots grow to a depth of 10 to 14 ft (3 to 4 m) enabling it to draw subsoil moisture from perched water tables. It will tolerate alkaline/saline soils as well as tall wheatgrass, but is considerably more drought tolerant. It grows best on loam and clay prairie soils.

Prairieland Altai wildrye produces forage which is palatable throughout the year. Its most common usage is for standing hay for winter consumption. The growth period is from early spring through fall. Some certified seed has been available from Canadian growers. Uncertified domestic production should be available by the spring of 1983.

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GRASSES FOR REVEGETATION OF MOUNTAIN SITES

Wendell Hassell, Jack Carlson, and Jim Doughty

ABSTRACT: Cool-season grasses are important to revegetation seed mixtures for mountain sites in the Intermountain West. Selection of species depends on knowing their characteristics and adaptation. Twenty-four recommended speices are described.

INTRODUCTION

Many mountain ranges in the Intermountain region of the Western United States have relatively high precipitation and support mountain shrubs, woodlands, and alpine vegetation. A variety of grasses are found growing throughout these vegetative zones.

In this paper, mountain sites are defined as areas where mean annual precipitation exceeds 18 inches (46 cm). These areas have shrub and grasslands in the high mountain parks and valleys and contain ponderosa pine, Douglas-fir, spruce-fir, and alpine communities. The sagebrush and pinyon-juniper woodland communities are generally excluded.

Several perennial grasses native to mountain sites and useful in reseeding programs are commercially available. Other potentially useful native grasses are not currently available or are in short supply. Some introduced grasses having similar attributes and adaptations are commercially available and can be substituted for these.

We describe 18 major and 6 minor native or introduced grass species recommended for revegetation of mountain sites. Table 1 lists selected characteristics of all 24 species, and table 2 describes their range of environmental adaptation. Information is based on the references listed at the end of this paper and on work by three USDA Soil Conservation Service Plant Materials Centers (PMC's) in the Intermountain region. The PMC's are at Aberdeen, Idaho; Pullman, Wash.; and Meeker, Colo.

Wendell Hassell and Jack Carlson are Plant Materials Specialists, USDA-Soil Conservation Service, Denver, Colo., and Portland, Oreg., respectively; and Jim Doughty is a State Range Specialist, USDA-Soil Conservation Service, Reno, Nev.

Only cool-season grasses are considered. These grasses grow actively during mild winters, develop rapidly and flower in spring and early summer, become relatively dormant during the summer, and resume growth in the fall. Cool-season grasses have C-3 photosynthetic pathways.

With two exceptions, all species described flower in May to June and produce mature seed in June to July. The exceptions are alpine timothy and tufted hairgrass, which flower in June to July and produce mature seed in July to August, except at higher elevations, such as alpine meadows, where mature seed may not be produced until late August or early September.

INTERPRETATION OF THE TABLES

Table 1: Selected Characteristics of the Grasses

Longevity.--Short-lived (S) stands begin to decline dramatically after 3 or 4 years and are gone 10 years after planting. Long-lived (L) stands do not begin to decline for at least 5 to 7 years, and usually last 10 to 20 years with proper management on adapted sites.

Seeding growth.--Ratings are relative. Perennial ryegrass is a standard rapidly developing grass; hard fescue is slow developing. Under optimum conditions, ryegrass may provide greater then 50 percent cover in 45 days; hard fescue would require an entire growing season. Many rapidly developing grasses are short-lived. Erosion-control seed mixtures usually include both rapidly developing species, and persistent, but slowly developing species.

Herbage volume.--Ratings are relative. Production of herbage varies by site, season, use, and other factors in addition to inherent capability.

Forage quality.--Ratings are relative. Cool-season pasture grasses are rated high; native range grasses may be rated somewhat lower. Grasses for special uses such as turf or erosion control may also be low in forage quality.

Table 2: Environmental Adaptation

Precipitation.--The minimum or range of mean annual precipitation tolerated by each species is recorded. For example, intermediate wheatgrass is adapted where mean annual precipitation is at least 14 inches (35 cm).

Table 1.--Selected characteristics of cool-season grasses for mountain sites (See text for explanations of columns 2, 3, 5, and 6)

Plant name	Longevity[1]	Seedling growth[2]	Season of forage use by livestock only	Herbage volume[3]	Forage quality[4]	No. seed/lb	Seed/ft^2 at 1 lb/acre
Alpine timothy	L	S-M	summer	L	F	1,680,000	38
Arizona fescue	L	S-M	summer	L	F-G	550,000	13
Big bluegrass	L	M	spring	M	G	917,000	21
Blue wildrye	S	R	spring, early summer	M	F	131,000	3.1
Canada bluegrass	L	S-M	early summer	L	F	2,500,000	57
Canby bluegrass	L	S	spring	L	F-G	296,000	21
Columbia needlegrass	L	S-M	spring, early summer	M	F-G	200,000	4.6
Creeping foxtail	L	S-M	late spring, summer	M-H	G	900,000	21
Creeping red fescue	L	S	late spring, summer	L	F-G	615,000	14
Hard fescue	L	S	late spring, summer	L	F-G	565,000	13
Intermediate wheatgrass	L	M-R	late spring, early summer	M	VG	100,000	2.4
Kentucky bluegrass	L	S-M	late spring, summer	L	F-G	2,100,000	50
Meadow brome	L	R	spring, summer	M	E	80,000	1.8
Mountain brome	S	VR	spring, early summer	M	VG	90,000	1.9
Orchardgrass	L	M	spring, early summer	M	E	540,000	12
Perennial ryegrass	S	VR	spring	M-H	G	247,000	5.7
Prairie junegrass	L	S-M	summer	M	G	700,000	16
Sheep fescue	L	S	late spring, early summer	L	F-G	680,000	16
Slender wheatgrass	S	R	spring	M	G	167,000	3.7
Smooth brome	L	R	spring, summer	M	E	125,000	2.9
Tall fescue	L	M	spring, early summer	M-H	G	230,000	5.3
Tall oatgrass	S	R	spring, early summer	M	G	150,000	3.5
Timothy	L	M	spring, early summer	M	VG	1,300,000	30
Tufted hairgrass	L	M	summer	M	F	2,500,000	57

1 L = long lived; S = short lived.
2 S = slow; M = moderate; R = rapid; VR = very rapid.
3 L = low; M = medium; H = high.
4 F = fair; G = good; VG = very good; E = excellent

Table 2.--Environmental adaptation of cool-season grasses for mountain sites (See text for explanations of columns 2, 3, 4, 5, 7, 9, 10, and 11)

Plant Name	Precipitation, inches	Temperature, °F	Inundation, days	Fertility Requirements[1]	Soil Texture	Shallow Soils[2]	Reaction, pH	Salinity Tolerance[3]	Drainage[4]	Heat Tolerance
Alpine timothy	>20	-50	[6]49-63	L	clay loam to sandy loam	Y	5.5-7.5	MS[6]	P-W	F
Arizona fescue	>10	-40	[6]14-21	L	clay loam to sandy loam	Y	6.0-7.5	MS[6]	MW-W	G
Big bluegrass	>10	-40	[6]7-14	L	clay loam to sandy loam	Y	6.0-8.0	MS[6]	SP-W	G
Blue wildrye	>16	-30	[6]21-35	L	clay loam to sandy loam	N	5.5-7.5	MS[6]	W	G
Canada bluegrass	>18	-40	[6]21-35	L	clay loam to sandy loam	Y	5.0-7.5	MS	SP-W	F
Canby bluegrass	>7	-40	[6]7-14	L	clay to sandy loam	Y	6.0-8.0	MT[6]	SP-W	G-E
Columbia needlegrass	>14	-40	[6]14-21	L	clay loam to sandy loam	Y	6.0-8.0	MT[6]	W	G
Creeping foxtail	>20	-40	49-63	M	clay to loam	N	5.0-8.0	MT	P-W	G
Creeping red fescue	>18	-40	21-35	L	clay to sandy loam	Y	5.0-7.5	MS	SP-W	F-6
Hard fescue	>14	-40	[6]21-35	M	clay to sandy loam	Y	5.5-7.5	MS	SP-W	G
Intermediate wheatgrass	>14-30	-30	21-35	M	clay loam to sandy loam	N	6.0-7.5	MS	MW-W	G
Kentucky bluegrass	>18	-40	21-35	M	clay loam to sandy loam	Y	6.0-7.5	MS	MW-W	F-G
Meadow brome	>16	-40	24-38	M-H	clay to sandy loam	N	5.5-7.5	MT[6]	SP-W	F-G
Mountain brome	>18	-40	[6]24-28	M	clay to sandy loam	N	5.5-7.5	MS	SP-W	F
Orchardgrass	>18	-20	14-21	H	clay to sandy loam	N	6.0-7.5	MS	MW-W	F-G
Perennial ryegrass	>18	-30	14-21	H	clay to sand	N	6.0-8.0	MT	P-SE	G
Prairie junegrass	>14	-40	[6]14-21	L-M	clay loam to sand	Y	6.5-8.0	MT[6]	W-SE	G
Sheep fescue	>10	-40	[6]14-21	L	clay to sandy loam	Y	5.5-7.5	MS[6]	MW-W	G
Slender wheatgrass	12-30	-40	49-63	M	clay loam to loam	N	6.0-9.0	T	MW-W	G
Smooth brome	>15	-40	24-28	M-H	clay loam to sandy loam	N	5.5-7.5	MT	SP-W	F-G
Tall fescue	>18	-40	21-35	M	clay to sandy loam	N	5.5-8.5	MT	P-W	G
Tall oatgrass	>20	-30	[6]21-35	L-M	silt loam to loamy sand	N	5.5-7.5	MS[6]	W-SE	F
Timothy	>20	-40	49-63	M	clay to sandy loam	N	5.0-7.5	MS	P-W	F
Tufted hairgrass	>20	-40	[6]49-63	L-M	clay to sandy loam	N	50-7.5	T[6]	P-W	F

1 L = low; M = moderate; H = high.
2 Y = yes; N = no.
3 MS = moderately sensitive; MT = moderately tolerant; T = tolerant.
4 P = poorly; SP = somewhat poorly; MW = moderately well; W = well; SE = somewhat excessively.
5 F = fair; G = good.
6 Unknown but probable.
7 'Paiute' is adapted where precipitation is greater than 10 inches.

Temperature.--The figures are general guidelines, corresponding to plant hardiness zones (USDA-ARS 1960). For example, intermediate wheatgrass can be expected to do well in zones where the minimum winter temperature is above -30° F (34° C) (the expected minimum in hardiness zone 4).

Inundation.--This indicates the number of days of inundation to a depth of at least 12 inches (30 cm) a species can withstand in the early to late spring during the normal period of peak runoff and prolonged flooding.

Fertility requirements.--Fertility depends on site conditions that vary widely. Therefore, the requirements are expressed in relative terms. Cool-season pasture grasses such as tall fescue, which have high moisture requirements, usually need high levels of nutrients, particulary nitrogen. Native range grasses generally have lower fertility requirements.

Shallow soils.--This is a rating of the suitability of the species for long term cover on shallow soils without maintenance practices such as irrigation and fertilization. Many of the rapidly developing grasses can provide temporary cover on shallow soils.

Salinity tolerance.--This is usually expressed as a function of salinity (electrical conductivity, ECe, in millimhos per cubic centimeter) and percentage of relative crop yield (Maas and Hoffman 1977).

Rating	Upper limit of salinity for-- 100% yield	50% yield	No live plants
	--millimhos per cubic centimeter--		
Sensitive	1.5	5.0	8.0
Moderately sensitive	3.0	10.0	16.0
Moderately tolerant	6.0	15.0	24.0
Tolerant	10.0	20.0	32.0

Drainage.--Standard terminology of the National Cooperative Soil Survey is used (USDA-Soil Survey Staff 1982).

Heat tolerance.--The relative ratings are based on the ability of plants to withstand high-intensity sunlight and high summer temperatures. Desert grasses that can withstand several days of temperatures above 100° F (38° C) are considered to have excellent heat tolerance. Grasses seldom are well adapted to cool, shaded locations, and most species have at least fair heat tolerance.

DESCRIPTIONS OF MAJOR GRASSES

Arizona fescue. See "Hard Fescue."

Big Bluegrass. See "Canada bluegrass."

Canada bluegrass

Canada bluegrass (*Poa compressa* L.), a low-growing, sod-forming introduced grass, provides good ground cover on open, dry, infertile soils. It tolerates acid soils and low fertility and is generally used for erosion control on roadsides, borrow pits, and dam sites, and as a low-maintenance turf in recreation areas. It is the most widely used bluegrass for conservation on mountain sites in the Intermountain area. Kentucky bluegrass (*P. pratensis* L.) is a common turf plant, but it is less preferred for reclamation because it has higher fertility requirements and less shade tolerance than Canada bluegrass.

Big bluegrass (*P. ampla* Merr.) and canby bluegrass (*P. canbyi* [Scribn.] T. Howell) are drought-tolerant native bunchgrasses that can be used on very dry mountain sites.

'Reubens' Canada bluegrass is the recommended cultivar for mountain sites in the West and is widely used. It was selected from a naturalized stand in northern Idaho and has better seeding vigor, ground cover, and seed production than common types. 'Draylar' upland bluegrass (*P. glaucantha* Gaudin) is a closely related species with similar attributes. Both are commercially available.

Numerous Kentucky bluegrass cultivars are available, primarily for turf. 'Troy' was released for horse pasture and is taller than the others. Cultivars with proven adaptation to a particular locality should be used.

'Sherman' big bluegrass and 'Canbar' canby bluegrass are the only cultivars of their species. Both were developed by the Pullman PMC and are commercially available.

Canby bluegrass. See "Canada bluegrass."

Creeping foxtail

Creeping foxtail (*Alopecurus arundinaceus* Poir.) is a cold-tolerant, sod-forming introduced grass that is adapted to wet meadowland sites in the Intermountain West. It forms a dense sod with strong rhizomes. It is very cold-tolerant and can persist where the frost-free period averages less than 30 days. Creeping foxtail is well adapted for meadowland and hay and for shoreline stabilization on ponds, lakes, streams, and waterways.

'Garrison' is the only cultivar of this species. It produces good quality forage on wet sites where it generally is superior to reed canarygrass and other wetland grasses. Seed is light and difficult to drill without rice hulls or a similar diluent. Seed is available from several commercial sources.

Creeping red fescue. See "Hard fescue."

Hard fescue

Hard fescue (*Festuca longifolia* Thuill.) is a low-growing bunchgrass introduced from Europe and widely used for highway plantings, airport strips, and other areas where a low-growing, persistent, competitive ground cover is needed. Although seedlings are slow to establish, plants become competitive through the development of abundant fibrous roots. Arizona and sheep fescue (*F. arizonica* Vasey and *F. ovina* L.) are similar to hard fescue but are more drought tolerant. Creeping red fescue (*F. rubra* L.) is less drought tolerant than hard fescue but is

sod-forming. All these fescue species are low growing and fine leaved.

'Durar' hard fescue, developed by the Pullman PMC, is a widely used cultivar in the West for seeding cut-over or burned timberland and for erosion control. Seed is readily available.

'Covar' sheep fescue is a recent release by the Pullman PMC. It has performed well on firebreaks by preventing invasion of tall weedy species and brush and providing a low-volume, fire-resistant cover. 'Covar' performs well on dry, harsh sites. Seed is available from commercial sources.

'Redondo' Arizona fescue, a native cultivar selected by the Los Lunas, New Mexico, PMC, is adapted to the southern part of the Intermountain area in woodland and forest plant communities. Some commercial seed is available.

Numerous cultivars of creeping red fescue are available, mostly for turf uses. 'Pennlawn,' a Northeast variety, can be used on mountain sites in the Intermountain West where precipitation exceeds 18 inches (46 cm). 'Fortress' is also adapted for erosion-control seedings.

Intermediate wheatgrass

Intermediate wheatgrass (Agropyron intermedium [Host] Beauv.) is a sod-forming, introduced grass. It is commonly planted with alfalfa for hay or pasture and is also frequently seeded after burns and used for erosion control work. It has good seedling vigor on mountain sites and can survive unseasonal drought or cold. Intermediate wheatgrass is one of the better choices for forage plantings, approaching the value of smooth or meadow brome, but more tolerant of harsh sites.

'Greenar' intermediate wheatgrass, developed at Pullman, Wash., is typical of the species and was selected for forage production and compatability with alfalfa. It is mildly sod-forming. Seed is available in low to moderate amounts--about 10,000 to 15,000 lb (4,500 to 7,000 kg) each year.

'Oahe' is a four-clone synthetic developed in South Dakota for improved seed production, forage yield, and rust resistance. It is well adapted to the Intermountain region, popular, and readily available.

'Tegmar' is a low-growing cultivar selected at Aberdeen, Idaho, for erosion-control attributes, including sod-formation and seedling vigor. Seed supplies fluctuate, but nearly 50,000 lb (23,000 kg) were produced in 1980.

Kentucky bluegrass. See "Canada bluegrass."

Meadow brome.

Meadow brome (Bromus biebersteinii Roem. and Schult.) is similar to smooth brome in characteristics and adaptation. It differs from smooth brome in that it has a bunchgrass or only slightly spreading habit, lacks abundant rhizomes, and is more susceptible to frost heaving at high elevations. 'Regar' meadow brome is a high producing, high quality forage that should be considered for the better mountain soils.

'Regar' meadow brome was developed by the Aberdeen PMC, and seed is readily available. In use and characteristics, it is similar to 'Manchar' smooth brome, except 'Regar' is slightly earlier. In erosion-control mixtures, 'Manchar' is more competitive than 'Regar' and more likely to form solid stands.

Mountain brome

Mountain brome (Bromus carinatus Hook. & Arn.) is a rapidly developing, somewhat short-lived native bunchgrass with a deep, well-branched root system. This species occurs on mountain sites throughout the Intermountain West. It is valuable for erosion control, and is well adapted for subalpine erosion-control seedings where a rapid, vigorous, cold-tolerant ground cover is desired. Plants are tall and erect and are heavy seed producers.

'Bromar,' released by the Pullman PMC, is the only cultivar. It is taller, leafier, and up to 2 weeks later than most other strains. Commercial seed production recently has increased substantially to annual production of 5,000 to 15,000 lb (2,300 to 7,000 kg).

Orchardgrass

Orchardgrass (Dactylis glomerata L.), an introduced bunchgrass, is highly palatable to livestock and is a preferred hay, pasture, or silage. It is compatible with alfalfa and clovers, but is less winterhardy than timothy and smooth brome. It also is included in erosion-control mixtures, particularly on cut-over or burned timberland, primarily for its forage value.

'Latar' orchardgrass was developed by the Pullman PMC. A commonly used variety for forage, it is lower in lignin and more highly digestible than other orchardgrasses. It is a late-season strain. Seed is available in quantity.

'Potomac,' developed in the Northeast, is an early-season variety often used in erosion-control seedings. This cultivar has proven widely adapted to mountain sites in the West. Seed is available.

'Paiute' was selected by the USDA Forest Service, Intermountain Forest and Range Experimental Station, Utah Division of Wildlife Resources, and the Aberdeen Plant Materials Center, and was released in 1982. It is more drought tolerant than other strains. Seed will be available in spring 1985.

'Pomar' is a low-growing cultivar selected by the Aberdeen PMC for erosion control and for use as a cover crop in orchards. In mixtures, it is also adapted for roadbank stabilization in mountainous areas where a low-volume cover is desired. Seed is not available at this time.

Numerous other orchardgrass cultivars are commercially available, but they vary widely in adaptation and attributes. Substitutions for the

above varieties should be made only after consultation with qualified specialist.

Perennial ryegrass

Perennial ryegrass (Lolium perenne L.) is a nutritious, palatable, introduced bunchgrass that develops rapidly from seed. It has high nutrient requirements, and therefore usually is a short-lived component of erosion-control seed mixtures. It does best where winters are mild, but will perform adequately where they are severe. In the Intermountain West, perennial ryegrass is recommended for use as rapid cover only if mountain brome or slender wheatgrass are not available. Perennial ryegrass is preferred over annual ryegrass (L. p. var. multiflorum [Lam.] R. Parnell), which is very competitive and can be allelopathic to other plants in the seed mixture.

Numerous cultivars of perennial ryegrass are available, although no specific recommendations are made for the Intermountain area. Many are turf types, but several vigorous tetraploid varieties have been developed for short-rotation pasture or green chop. Tetraploid varieties are preferred for erosion control.

Sheep fescue. See "Hard fescue."

Slender wheatgrass

Slender wheatgrass (Agropyron trachycaulum [Link] Malte ex H.F. Lewis) is a short-lived native bunchgrass with good seedling vigor. It is a valuable component of erosion-control seed mixtures because it develops rapidly, is compatible with other species, and tolerates a wide range of site conditions. New selections are proving well adapted to high elevations but are a few years away from official release and commercial seed production.

'Revenue,' a Canadian variety originating from Saskatchewan, was selected for salinity tolerance, seed set, and forage yield. It is not well tested in the Intermountain West but probably can be used with success. Most slender wheatgrass planted is common seed harvested mainly from fields in the north-central United States. Check pure live seed and weed content, as well as source before buying.

Smooth brome

Smooth brome (Bromus inermis Leyss.) is a rapidly developing, sod-forming, introduced grass widely used for pasture, hay, silage, and erosion control. It rates high in palatability and nutritive value. Smooth brome is separated into northern and southern types. For mountain sites in the Intermountain West, northern or intermediate types should be used.

'Manchar' is the preferred and most commonly used variety of smooth brome for mountain sites. Developed by the Pullman PMC, the seed is readily available. It germinates rapidly, grows vigorously, produces large amounts of forage, and is compatible with alfalfa or hay. It can be used in erosion-control mixtures.

Tall fescue

Tall fescue (Festuca arundinacea Schreb.) is a tall, coarse, flat-bladed, introduced bunchgrass that has wide climatic and soil adaptation. It is widely used in pastures but also provides a tough, vigorous, competitive ground cover where desired. Tall fescue is less palatable than other pasture grasses, which may be grazed out of a stand if mixed with it. However, its value as a forage should not be overlooked.

'Alta' and 'Fawn' are standard cultivars that are well adapted to the Intermountain area. Both were developed in Oregon and are heavy, good quality forage producers, and excellent seed producers. Seed is readily available.

'Kenhy' is a hybrid of tall fescue and perennial ryegrass. It is more palatable than regular strains of tall fescue, but retains its wide adaptation, production, and resiliency. Seed is available.

Timothy

Timothy (Phleum pratense L.) is an introduced bunchgrass adapted to cool, humid areas. It does well on wet meadowland sites. Timothy hay is sold at premium prices for horse feed and is compatible with alfalfa. It also is used for ground cover on cut- or burned-over timberland and is not overly competitive with tree regeneration.

'Climax' and 'Drummond' timothy are Canadian cultivars that have been commonly used in the West. Private breeding efforts are resulting in new cultivars that may prove useful in the Intermountain area. 'Climax' is the most readily available cultivar.

DESCRIPTIONS OF THE MINOR SPECIES

Several other grasses could be used to revegetate mountain sites in the Intermountain West if seed were more readily available or if cultivars were developed and released for commercial production. For some of these grasses, the seed is available sporadically and in limited quantities, often from harvests of native stands.

Alpine timothy

Alpine timothy (Phleum alpinum L.) is a low-growing native bunchgrass in high mountain meadows and moist seeps. It shows promise for revegetation of disturbed sites in alpine and subalpine areas. Seed is occasionally available in very small quantities. Because little is known about this plant, local seed sources should be used.

Blue wildrye

Blue wildrye (Elymus glaucus Buckley) is a rapidly developing, short-lived native bunchgrass with attributes similar to those of mountain brome and slender wheatgrass. It is unusual in that test plantings show it to be compatible with tree regeneration. Blue wildrye is widespread throughout mountainous areas of the West and has many forms.

If seed happens to be available, use only local sources from within 300 miles (500 km) and 1,500 ft (500 m) elevation of the intended site. Selection work is under way to develop adapted cultivars.

Columbia needlegrass

Columbia needlegrass (Stipa columbiana JN. Macoum.) is a long-lived native bunchgrass in mountainous areas of the West, including subalpine areas. It is drought tolerant and can form good ground cover on dry, rocky, infertile sites. Seed is not available, but testing is under way to develop adapted cultivars. A similar species is Letterman needlegrass (S. lettermanii Vasey), which occurs at higher elevations and holds promise for erosion-control.

Green needlegrass (Stipa virdula Trin.) occurs mostly east of the Continental Divide. It is available commercially and could be considered for use in seed mixtures in the eastern portion of the Intermountain area. The adaptation information in tables 1 and 2 applies only to Columbia and Letterman needlegrass.

Prairie junegrass

Prairie junegrass (Koeleria cristata [L.] Pers. Nutt.) is a native bunchgrass on rocky slopes and in woodlands and open forests. It forms scattered stands and is seldom abundant. It is drought tolerant and is a useful component of ground-cover mixtures if seed is available. Prairie junegrass greens early and is readily grazed in spring. Commercial seed is not available.

Tall oatgrass

Tall oatgrass (Arrhenatherum elatius [L.] J. & K. Presl) is a rapidly developing, short-lived, introduced bunchgrass with uses similar to those of slender wheatgrass. 'Tualatin' is an old variety that once was commonly used for seeding logging roads, cut-over timberland, and other disturbed areas. Seed shattering, with resultant low seed yields, has been the major obstacle to greater acceptance. Very little commercial seed is available.

Tufted hairgrass

Tufted hairgrass (Deschampsia cespitosa [L.] Beauv.) is a native bunchgrass in wet meadows and along streambanks at high elevations. It has good potential for erosion control and streambank plantings at high elevations. Limited seed is available from native harvests, but selection work is under way to develop adapted cultivars.

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PLANTS ADAPTED TO SUMMER RANGELANDS

Neil C. Frischknecht

ABSTRACT: Disturbances resulting from overgrazing, timber harvesting, mining, recreation, and installation of roads, powerlines, and reservoirs require artificial revegetation of summer rangelands for: (1) control of runoff and erosion, and (2) restoration of forage production for domestic livestock and big-game animals. Quick establishment of an effective vegetative cover for soil protection that will remain productive indefinitely requires proper selection of plant species suited to a variety of ecological conditions.

INTRODUCTION

Summer rangelands in the Western United States are, for the most part, mountain lands. Lowland meadows are frequently grazed in summer by cattle and other livestock. Cattle can also be pastured on foothill crested wheatgrass[1] range in summer if they are fed a small amount of protein supplement (Harris and others 1968). Despite possibilities for summer grazing on lowland ranges, this paper will deal with plants adapted to the high mountain ranges of the Intermountain region. Disturbances resulting from overgrazing, timber harvesting, mining, recreation, and installation of roads, powerlines, and reservoirs require artificial revegetation of high summer rangelands for: (1) control of runoff and erosion, and (2) restoration of forage production for domestic livestock and big-game animals.

Seeding experiments using grasses on mountain ranges began in Wyoming in 1897 and in Washington State in 1901 (Laycock 1982). The establishment of the Great Basin Experiment Station in Ephraim Canyon in central Utah in 1912 resulted from the need to study ways of restoring plant cover on depleted ranges and to determine which species would be most useful for this purpose (Keck 1972). Much of the information on adaptability of species presented in this paper comes from the long-term results on that area. Testing sites were established at different elevations in Ephraim Canyon ranging from 5,600 to 10,500 ft (1 707 to 3 201 m) to evaluate the performance of a variety of grasses, forbs, and shrubs. Pilot plantings of the most successful species were then established on various sites to further test their adaptability. Both native and introduced species were tested in the earliest trials and that practice continued as new plant materials became available.

Neil C. Frischknecht recently retired as a Range Scientist from the USDA Forest Service, Intermountain Forest and Range Experiment Station.

[1]Scientific names are listed in table 1.

CHARACTERISTICS AND PROBLEMS OF HIGH MOUNTAIN RANGES

In central Utah, precipitation increases with altitude (Lull and Ellison 1950). Areas above 8,000 ft (2 439 m) elevation will receive around 25 inches (63.5 cm) or more annual precipitation. Some mountain ranges will average 40 inches (101.6 cm) or more.

Another feature of high mountain lands is the relatively short growing season. The average length of the growing season in the transition zone between oakbrush and aspen is 100 days. In the middle aspen zone of 9,000 ft (2 700 m), the average length of the growing season is 90 to 100 days; at 10,500 ft (3 470 m) elevation, 80 days. Plants adapted to these high ranges must be able to produce seed in the short growing season or perpetuate vegetatively.

Soil stabilization capability is an important characteristic of species selected for seeding subalpine lands. On some areas, soil is thin and plants are needed that can check further loss of soil. Much topsoil has eroded from mountain rangelands because of past overgrazing. Before establishment of National Forest reserves, domestic livestock followed the snowline as it receded up the mountain in spring. This resulted in early use before plants were ready for grazing. Often too many animals and too much use accentuated the problem. The most palatable plants were destroyed, and accelerated erosion ensued, particularly on steep slopes. In the 1890's, large bands of sheep grazed these ranges. The abuse to the vegetation and soil caused severe floods in the valleys below. Residents appealed to the Federal Government to have the mountain lands set aside in preserves so that grazing could be regulated and flood damage stopped.

The aspen community has the potential of being one of the most productive of all mountain vegetation types in terms of forage for livestock and big game. Unfortunately many aspen areas were severely depleted of understory vegetation by the early history of overgrazing. Despite improvement in the last 30 years, many aspen sites are still producing below their forage potential, and opportunity exists for increasing forage production.

A factor that will preclude the improvement of aspen sites for forage is the encroachment of conifers, if their invasion is unchecked. Over 70 percent of the aspen lands in the Rocky Mountain area are being invaded by conifers that greatly reduce species diversity and forage

output (Wagstaff, personal communication). Because of the timber value of conifers, Wagstaff feels that allowing conifers to invade and dominate aspen sites reduces the present value of these lands without conifers by over $100 per acre.

USE OF INTRODUCED AND NATIVE SPECIES

This paper emphasizes the use of both introduced and native species adapted to high summer ranges. Common introduced species used in early trials at the Great Basin Station included smooth brome, orchardgrass, Kentucky bluegrass, timothy, crested wheatgrass, alfalfa, and sweetclover (Forsling and Dayton 1931).

All these species, with the possible exception of crested wheatgrass, were planted in hay meadows across the northern part of the United States. Their seeds were carried into the mountains by early settlers to raise hay for horses. Perhaps Kentucky bluegrass is the most prominent in this regard, particularly along streams. These species are now so common and widespread that many people fail to recognize them as introduced.

Other introduced species used in early tests through the 1920's at the Great Basin Station included, among sod-formers, Canada bluegrass and redtop, and, among bunchgrasses, meadow fescue and tall oatgrass. Native species included slender wheatgrass and mountain brome, both bunchgrasses found on high mountain ranges. Other native wheatgrasses valuable for additional testing included bluebunch and beardless bunchgrasses, and bluestem, streambank, and thickspike, all sod-formers (Forsling and Dayton 1931). These species and many others were tested at different elevations at the Great Basin Station and other places throughout the West over many years and are recommended for planting (Plummer and others 1955, 1968).

Plant selection and breeding have gone on longer in the case of introduced species than with native species, although increased effort is being given to natives. Both herbage and seed yields from many introduced species are superior to the yields for natives. Generally speaking, introduced species often germinate more readily and become established more rapidly than natives, and thus can form an early vegetative cover to protect the soil while native species are developing. An exception would be native mountain brome, a short-lived bunchgrass that establishes quickly from seed on high mountain ranges. As discussed earlier, many introduced species have wider ecological amplitude than native species and are adapted to a greater variety of sites. In the opinion of this author, natural selection under heavy animal use in the Old World has produced some cool-season grasses that are more resistant to grazing than many of our native cool-season grasses, particularly the wheatgrasses. Work by Caldwell and others (1981) would tend to substantiate this premise.

In addition to individual plots, various combinations of introduced and native species were used in larger plantings in the vicinity of the Great Basin Station in aspen openings, aspen canopy, and higher subalpine areas. In the early 1940's seed of native mountain brome, a bunchgrass, and smooth brome were hand broadcast on a long, linear aspen opening that was totally devoid of vegetation except for scattered clumps of red elderberry. Erosion pavement in the form of small gravel protected the ground surface from further erosion. The seed was covered by use of a log harrow plus trampling the area by a herd of sheep. Either of these treatments alone would have been sufficient to cover seed. An excellent stand of grass resulted with mountain brome dominating for about 10 years. Some 40 years later, smooth brome dominates the site. Mountain brome is found mostly in the elderberry patches.

One of my early assignments at the Station was to sample the success of a 1,300-acre (525-ha) seeding in aspen and oakbrush where seed of six introduced grasses and two legumes had been broadcast by airplane a year earlier (Stewart and Plummer 1947). Grasses included smooth brome, orchardgrass, timothy, Kentucky bluegrass, tall oatgrass, and crested wheatgrass. The legumes were alfalfa and yellow blossom sweetclover. Seed was broadcast at an average rate of 11 lb per acre (13 kg/ha), October 2-9, 1945. Sampling involved counting seedlings on transects of temporary plots in September 1946 and again in September 1947. Data from 156 plots, each 10 ft^2 (0.93 m^2), in 1946 showed an average of 8.9 and 7.5 grass seedlings per plot on two aspen areas and 7.4 seedlings per plot on an oakbrush site. No young plants were found on 61 of the plots; over 60 plants were found on some others.

In 1947, of 298 plots sampled only 29 showed no plants. Numbers of plants had increased slightly from the previous year to an average of 10.9 plants per plot in aspen and 9.0 plants per plot in oakbrush. After 36 years, these areas were producing vigorous stands of grasses underneath the aspen and oak canopies. Tall spindly seedlings that were growing in the shade of trees the first year or two following seeding have developed into a highly productive understory, with smooth brome and orchardgrass being most prominent.

In the early 1950's, the effectiveness of reseeding plus contour trenching in the subalpine zone was demonstrated on a small 10-acre (4-ha) experimental watershed (watershed B) at the head of Ephraim Canyon (Meeuwig 1960). Up to 1946, this small watershed had a reasonably good ground cover amounting to about 40 percent. Between 1948 and 1951, this area was intentionally depleted by heavy grazing to 16 percent ground cover, and it became a potential flood source. During this period of depletion, watershed B produced more than four times as much runoff and 12 times as much sediment as watershed A, which had been maintained at approximately 40 percent native ground cover.

In 1952, depleted watershed B was treated to restore vegetative cover and reduce erosion by disking and installing contour furrows on the steeper slopes. A mixture of one native and four introduced grasses plus three legumes was then broadcast on the area at a rate of 20 lb per acre (22.4 kg/ha). Grasses included native mountain brome, orchardgrass, meadow foxtail, smooth brome, and erect brome. Native mountain lupine, nomad alfalfa, and chickpea milkvetch comprised the legumes.

The greatest storm severity of record to that time occurred in the first growing season (1953) following restoration. The seeded grasses had not yet developed a vegetative cover adequate to control runoff and erosion, but the contour trenches provided the necessary control. In that severe storm year, watershed B produced only one-third as much surface runoff and one-tenth as much sediment as watershed A, which was regarded to be in good condition. Since then, the combination of vegetative cover and contour trenches has effectively eliminated runoff and erosion from this area. Although mountain brome was most prominent in early years, smooth brome, a sod-former, has developed as the most abundant grass on the area 30 years following treatment. All species are present to some degree.

Table 1 lists selected native and introduced species that have been found adapted to high summer rangelands (Plummer and others 1955, 1968; Hall 1974). Many other species are also adapted to these areas but have not been widely tested. Grasses in table 1 show an overall wider adaptability than forbs and shrubs. Their fibrous root system is generally superior for binding and holding the soil.

I have observed that both native and introduced rhizomatous species can survive hot fires better than bunchgrasses where heavy debris from trees is burned. Also, it is well known that rhizomatous species can provide better ground cover than bunchgrasses and hold soil in place because of vegetative spread and development. Rhizomatous species often develop more slowly than bunchgrasses, but they can eventually become dominant.

Most broadleaf forbs in table 1 are native, but such introduced legumes as Ladak alfalfa, cicer milkvetch, and alsike clover can add to the productivity and fertility of soils low in nitrogen (Laycock 1982). These legumes have shown outstanding ability to pioneer on raw sites, as have several other forbs (Plummer and others 1955). In general, forbs add to the nutritive quality of the forage, particularly in summer and early fall when many grasses are approaching seed maturity and their palatability is declining. All forbs listed are good natural spreaders from seed.

Along with forbs, shrubs add to the diversity of vegetation and contribute to the overall plant cover on mountain ranges. All shrubs on the list are native and will reproduce from seed. Shrubs can often become established on sites where the soil is lacking in fertility adequate for good grass growth (Plummer and others 1955).

Various cultivars of many species shown in table 1 possess traits superior to others for various sites (Plummer and other 1955, 1968; Hull 1974).

Seeds of all introduced grasses and many native grasses on the list are commercially available, as they are for the most prominent forbs. Seeds of many native forbs and nearly all shrubs listed have not long been commercially available. In recent years seed dealers have collected moderate amounts for sale, and they will collect upon request. In fact, collectors will have seeds of a great variety of native species available when there has been a relatively good seed year.

Prices for hand-collected seeds are usually high. Plant materials other than seeds have also become commercially available and can often be used to advantage in hastening plant establishment. These include bareroot stock and container-grown tubelings. In addition, cuttings of certain shrubs and trees can be used successfully, particularly ornamental sage and some of the willows and poplars. Wildings can be dug up and transplanted advantageously on small disturbed sites.

OTHER CONSIDERATIONS

In recent years, the interseeding of shrubs and other selected plants into already seeded grass stands to increase species diversity has come into prominence. This procedure can be used to advantage in aspen openings and subalpine areas as well as on lower foothill sites. A modified Sieco fireplow has been used with good success to clear strips of vegetation approximately 30 inches (0.76 m) wide (Monsen 1980; Stevens and others 1981). An alternative to clearing solid strips of existing vegetation is to make scalps at intervals and plant the seeds, bareroot stock, or container tubelings in the scalped spots.

Another implement used successfully on simulated mined spoils is the Hodder-gouger seeder. A hydraulic ram raises and lowers disks that gouge small basins, giving a wafflelike effect to the ground surface. Seed tubes broadcast seed behind the disks on the loose soil surface, and soil sloughing covers the seeds. It seems reasonable that this machine could be used in certain types of herbaceous vegetation to eliminate part of the competition and plant new species. The basins would help trap moisture and thus aid establishment of new seedlings. This would also contribute to reduced runoff and erosion by keeping precipitation on areas where it falls. In effect, the small basins are similar to those made by an eccentric disk, except that, in the case of the Hodder-gouger, competition would not be removed from spaces between gouges. This was designed mainly for seeding mine spoils where no other vegetation is present.

Table 1.--Plants adapted to high summer rangelands

Common name	Scientific name	Aspen canopy	Aspen openings	Subalpine	Alpine
		GRASSES			
Smooth brome*	Bromus inermis	x	x	x	x
Orchardgrass	Dactylis glomerata	x	x	x	x
Tall oatgrass	Arrhenatherum elatius	x	x	x	x
Kentucky bluegrass*	Poa pratensis	x	x	x	x
Timothy	Phleum pratense	x	x	x	x
Intermediate wheatgrass*	Agropyron intermedium		x	x	
Canada bluegrass*	Poa compressa			x	x
Mountain brome	Bromus carinatus		x	x	
Slender wheatgrass	Agropyron trachycaulum		x	x	x
Meadow brome	Bromus erectus		x	x	x
Meadow foxtail	Alopecurus pratensis		x	x	x
Reed canarygrass*	Phalaris arundinacea				x
Scribner wheatgrass	Agropyron scribneri				x
Alpine bluegrass	Phleum alpinum				x
Tufted hairgrass	Deschampsia caespitosa				x
Spike trisetum	Trisetum spicatum				x
Crested wheatgrass	Agropyron desertorum		x		
Meadow fescue	Festuca elatior	x	x		
Bluebunch wheatgrass	Agropyron spicatum		x		
Beardless bunchgrass	Agropyron spicatum inerme		x		
Bluestem wheatgrass	Agropyron Smithii		x		
Streambank wheatgrass	Agropyron riparium		x		
Thickspike wheatgrass	Agropyron dasystachyum		x		
Erect brome	Bromus erectus	x	x	x	
		FORBS			
Showy goldeneye	Viguiera multiflora	x	x	x	
Mountain lupine	Lupinus alpestris	x	x	x	
Porter ligusticum	Ligusticum porteri		x		
Cow parsnip	Heracleum lanatum	x			
Western yarrow*	Achillea millefolium			x	x
Sweet anise	Osmorhiza occidentalis		x	x	
Chickpea milkvetch	Astragalus cicer		x	x	x
Alsike clover	Trifolium hybridum		x	x	x
Ladak alfalfa	Medicago sativa		x	x	
Blueleaf aster	Aster glaucodes		x	x	
Pacific aster	Aster chilensis adscendens		x	x	
Horsemint	Agastache urticifolia	x	x		
Blue flax	Linum lewisii		x		
Rocky Mountain penstemon	Penstemon strictus		x		
Yellow blossom sweet clover	Melilotus officinalis	x	x		
Chickpea milkvetch	Astragalus cicer		x		
		SHRUBS AND TREE			
Mountain snowberry*	Symphoricarpos oreophilus	x	x	x	
Blue elderberry	Sambucus coerulea	x	x		
Shrubby cinquefoil	Potentilla fruticosa		x		
Oregon grape*	Mahonia repens	x	x		
Common juniper	Juniperus communis	x	x		
Red elderberry	Sambucus racemosa		x	x	x
Lanceleaf rabbitbrush	Chrysothamnus nauseosus		x	x	
Rothrock sagebrush	Artemisia rothrockii			x	
Gooseberry currant	Ribes montigenum			x	x
Aspen	Populus tremuloides	x			

* Rhizomatous species.

A large front-end bucket 14 ft (4.27 m) long and 9 ft (2.74 m) deep, known as the front-end sodder, is another new implement that can be used to move pads of vegetation to new areas. It has been used on mine reclamation projects to move pads of small aspen trees to sites being reclaimed. We have used it to move pinyon and juniper trees onto simulated mine spoils in the Emery coal field in central Utah. We found that scooping out a pocket for the tree or pad of vegetation gave better results than merely dumping the tree-pad on the surface. The soil scooped from the basin was then placed in the hole from which the previous tree-pad of vegetation was removed. In the case of aspen trees, exchanging pads of vegetation might not apply where contiguous scoops are used to remove trees.

CONCLUSIONS AND RECOMMENDATIONS

Both introduced and native species are adapted and should be used for seeding high mountain ranges.

Grasses should form the basic element in all seed mixtures because of their fibrous root system and superior soil-binding qualities.

For superior ground cover and stabilizing raw sites, it is wise to include at least one rhizomatous grass such as smooth brome or intermediate wheatgrass in mixtures.

Alfalfa, chickpea milkvetch, alsike clover, and mountain lupine are superior legumes for seeding on raw sites as well as components for general seed mixtures.

Adapted forbs and shrubs can add to the diversity of vegetation and increase overall vegetative cover and forage production.

Merely broadcasting seeds before, during, or immediately following leaf fall in aspen and oakbrush areas can produce successful grass stands with no further covering of seed.

In the absence of deciduous leaves to cover seeds, as in most large aspen openings and subalpine sites, more intensive treatment is required to remove competition and prepare a seedbed. Plowing or disking can remove nearly all competition from herbaceous species on such areas. A field cultivator with duckfoot sweeps can remove 50 to 90 percent of the competition, depending upon species present. With the latter implement, twice-over is far more effective than once-over.

Conifers invading the aspen community pose a serious threat to forage productivity and species diversity. Tree encroachment could be controlled through greater cutting of Christmas trees and other means.

Contour trenching with a dozer and disk-plowing between trenches followed by seeding where the slope is less than 20 percent can restore badly eroded ranges. Where the slope is over 20 percent, disking between contour trenches is not recommended. On steep watershed areas where gullies exist, merely removing livestock grazing will not accomplish the needed results.

Interseeding and scalping can be used to remove competition to introduce shrubs or other selected plants into grassland and herbaceous areas where ground cover is otherwise good.

With the advent of reclaiming mine spoils, new equipment such as the Hodder-gouger seeder and front-end sodder have been developed. These can be used effectively in certain kinds of seeding operations in aspen openings and subalpine areas.

Where the terrain is reasonably flat, drilling of seed is recommended. However, broadcasting seed on newly treated areas in the fall can produce highly successful herbaceous stands because sloughing of loose soil over winter covers the seed. If seed is drilled, 10 to 12 lb per acre (11.2 to 13.4 kg/ha) is recommended in the higher mountain lands.

Trampling by livestock can help cover seed, particularly when seed is broadcast on burned areas.

Plant materials other than seeds have become commercially available and can often be used to advantage in hastening plant establishment. These include bareroot stock and container-grown tubelings. In addition, cuttings of certain shrubs and trees can be used successfully. Wildings can be dug up and transplanted advantageously on small disturbed sites.

All newly seeded areas should be protected from animal damage. This often requires fencing or removal of livestock for 2 years. Aspen openings and subalpine areas can usually be grazed lightly in the fall of the second growing season. In dense shade of aspen, plants often take longer to become firmly established; where such exist, protection from grazing longer than 2 years might be required.

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Section 4. Advances in Plant Selection and Development

PROMISING NEW GRASSES FOR RANGE SEEDINGS

K. H. ASAY

ABSTRACT: New cultivars of range grasses have recently been released by public agencies in the United States and Canada and other promising strains soon will be available. Some advanced generation strains derived through interspecific hybridization have shown promise. Two hybrid germplasms have been released and other strains are being evaluated for possible release.

INTRODUCTION

The improvement of range grasses through breeding has received comparatively little emphasis. In the past, many range reseedings were done with unimproved strains or varieties originally developed for the Great Plains. Breeders working to develop better germplasm have had a limited amount of genetic variability to select from. This problem has been especially serious for introduced grass species. Many cultivars of introduced grasses were derived from a single introduction. Recognizing the need for better cultivars of range grasses, researchers in the United States and Canada have accelerated plant introduction and breeding efforts. This paper discusses some of the new and potentially valuable grass germplasm generated by these programs.

RUSSIAN WILDRYE *Psathyrostachys juncea*

Once established, Russian wildrye provides an excellent source of herbage on arid and semiarid range. The species produces abundant early-season forage, is resistant to cold and drought, and has excellent forage quality. It retains its nutritive value during the late summer and fall better than many other range grasses, such as crested wheatgrass. However, some serious limitations have prevented Russian wildrye from reaching its full potential on Western range. The species has relatively poor seedling vigor and is difficult to establish on range sites. Stand failures are often due to the inability of seedlings to emerge from excessive planting depths. Also, commercial production of Russian wildrye seed is severely hindered by seed shattering problems soon after maturity (Rogler and Schaaf 1963; Smoliak and Johnston 1980b).

K. H. Asay is a Research Geneticist for the U.S. Department of Agriculture, Agricultural Research Service, Utah State University, Logan, Utah.

A breeding program was initiated in 1976 by the USDA Agricultural Research Service (USDA-ARS) in cooperation with Utah State University to develop improved cultivars of Russian wildrye. Seedling vigor under drought stress and exploration to expand the available genetic base have been the project's major concern. The most promising source of germplasm in this breeding program was derived from a recently introduced strain from the U.S.S.R. called 'Bozoisky'. Parental clones developed from this and other populations have been included in crossing programs to develop three experimental synthetic cultivars. These plant materials are being evaluated on several range sites and a cultivar release is expected in 1983 or 1984.

Two cultivars of Russian wildrye recently released from breeding programs in Canada are:

'Swift'

'Swift' was released in 1978 by Agriculture Canada at Swift Current, Saskatchewan. The parental materials were selected for improved seedling vigor primarily on the basis of seedling emergence from deep seedings. The cultivar has displayed excellent establishment characteristics in Canadian field trials (Lawrence 1979).

'Cabree'

This cultivar was developed at the Agriculture Canada Research Station at Lethbridge, Alberta. Selection was based primarily on seed retention (resistance to shattering), seedling vigor, forage yield, seed yield, and culm strength. In Canadian field tests, 'Cabree' shattered less seed than other cultivars, including 'Vinall' and 'Sawki' (Smoliak 1976).

ALTAI WILDRYE *Leymus angustus*

Altai, an introduction from the U.S.S.R., is a long-lived perennial that is beginning to gain acceptance in Western Canada and the United States. The species is larger and somewhat coarser than Russian wildrye. Also, the seed is larger and seedlings can emerge from relatively deep seedings better than Russian wildrye. The species cures exceptionally well and retains its nutritional value throughout the season better than most cool-season grasses. Because of these qualities and its erect culms that protrude through the snow, Altai has been proposed for extending the grazing season during the late fall and winter. The grass is reportedly well adapted to the loam and clay soils of the prairies of Manitoba, Saskatchewan, and Alberta (Lawrence 1976).

Altai has been noted for its extensive root system that can reach soil depths of over 10 ft (3 m) (Lawrence 1976; Lawrence and Lodge 1975). Early tests suggest that the salinity tolerance of Altai approaches that of tall wheatgrass (McElgunn and Lawrence 1973). The USDA-ARS at Logan has crossed Altai with related species, basin wildrye _L. cinereus_ and mammoth wildrye _L. giganteus_. Research has been initiated to develop fertile and genetically stable populations from these hybrids. One new cultivar of Altai wildrye has been released:

'Prairieland'

This cultivar was recently developed and released by the Agriculture Canada Research Station at Swift Current, Saskatchewan, and seed is now becoming generally available. 'Prairieland' was selected from two U.S.S.R. introductions on the basis of high seed and forage yield, freedom from leaf spot, and good seed quality (Lawrence 1976).

CRESTED WHEATGRASS _Agropyron cristatum_ _A. desertorum_ AND _A. fragile_

This complex, which consists of a series of diploid, tetraploid, and hexaploid species, has been the most widely used grass in revegetation programs on Western range. An estimated 8 million acres (3.2 million ha) have been established with crested wheatgrass in the United States (Newell 1955) and over 2 million acres (1 million ha) in Canada (Lodge and others 1972). Although the quality of crested wheatgrass forage declines rapidly during the summer months, it is still one of our best sources of early spring forage on semiarid range. Most of the research with this species complex in the United States is concerned with the tetraploids, _Agropyron desertorum_ (Standard) and _A. fragile_ (Siberian), and the diploid, _A. cristatum_ ('Fairway').

The tetraploid cultivars 'Nordan' and 'Summit' and the diploid cultivar 'Fairway' have been in common usage for several years. 'Fairway' is considered to be leafier than 'Nordan' or 'Summit,' but it is not as drought hardy as Standard (Knowles and Buglass 1971).

The USDA-ARS at Logan has developed three new synthetic strains of crested wheatgrass derived from Standard, induced tetraploid 'Fairway,' and the induced tetraploid 'Fairway' X Standard hybrid. These experimental cultivars are being evaluated on range sites and a release is expected in 1984. The crested wheatgrass hybrid has shown particular promise. It has excellent vegetative vigor relative to the parental species in both the seedling and mature plant stages. Three relatively new cultivars of crested wheatgrass are:

'Ruff'

This is a diploid cultivar developed cooperatively by the USDA-ARS and the Nebraska Agricultural Experiment Station. The parental germplasm was derived from 'Fairway' and was originally designated as Nebraska 3576. Ruff has a spreading, broad-bunch growth habit and the culms are comparatively leafy and short. It has been recommended for grazing during the early spring in the low precipitation zones of the Great Plains, and for areas such as roadsides, parks, and playgrounds in the drier semiarid regions (USDA Extension Service 1978).

'Ephraim'

This crested wheatgrass cultivar was jointly released in 1983 by the USDA-Forest Service, Utah State Division of Wildlife Resources, USDA-Soil Conservation Service (USDA-SCS), and the Agricultural Experiment Stations of Utah, Arizona, and Idaho. The original parental plant materials were collected near Ankara, Turkey. It is a persistent sod-forming cultivar that is adapted to the arid ranges of the Intermountain West. Extent of rhizome development is influenced by environmental conditions. On most pinyon-juniper and sagebrush-grass sites, rhizomes are reported to develop by the second or third year. Although annual biomass production of 'Ephraim' appears to be similar to 'Fairway,' its culm length is slightly shorter. Wolf plants, which commonly occur in stands of 'Fairway' and Standard, have not been observed in 'Ephraim' (Stevens and others[1/]).

'P-27'

A strain of the Siberian type, 'P-27' was developed by the USDA-SCS and released cooperatively with the Idaho Agricultural Experiment Station in 1953. The original collections were made in Kazakhstan, U.S.S.R. In general, Siberian wheatgrass is similar to Standard in appearance, but the leaves are more lax and narrow. The grass is reportedly adapted to sandy soils (Andreev 1974) and has greater frost tolerance than Standard (Hanson 1972).

INTERMEDIATE WHEATGRASS _Elytrigia intermedia_

This productive, versatile grass was introduced into North America from southern U.S.S.R. and central Asia. It is more productive, but somewhat less drought resistant than crested wheatgrass. Because of its large seeds and relatively vigorous seedlings, the species is

[1/]Stevens, R.; Monsen, S. B.; Shaw, N.; McArthur, E. D.; James, G.; Davis, G.; Jorgensen, K. R.; Davis, J. N. Notice of naming and release of 'Ephraim' crested wheatgrass; 1983.

considered one of the easiest range grasses to establish within the limits of its adaptation. It matures from 1 to 2 weeks later and is more productive during the summer period than crested wheatgrass. It has been used successfully in mixtures with alfalfa under dryland and irrigated conditions (Asay and Knowles[2/]; Rogler 1973).

Several cultivars of intermediate wheatgrass and its subspecies, pubescent wheatgrass (subsp. trichophora), have been released. 'Greenar,' 'Oahe,' 'Slate,' 'Tegmar,' 'Amur,' 'Chief,' 'Topar,' 'Luna,' and 'Greenleaf' were all released prior to 1970. One cultivar has been released since then:

'Clarke'

This is a new cultivar of intermediate wheatgrass released in 1980 by the Agriculture Canada Research Station at Swift Current, Saskatchewan. 'Clarke' has no visual characters that distinguishes it from other cultivars of intermediate wheatgrass. However, it is described as a cultivar with good drought resistance, winterhardiness, and high seed yield. During its development, improved vigor during establishment, disease resistance, and forage yield were also stressed. In Canadian trials, dry matter yields of 'Clarke' were equal to or higher than 'Chief' or 'Greenleaf.' 'Clarke' yielded substantially more seed than either of these cultivars (Lawrence 1981).

WESTERN WHEATGRASS Pascopyrum smithii

Western wheatgrass is a widely adapted cool-season species that is native to North America. It is resistant to environmental stress, has a rhizomatous growth habit, and is adapted to heavy, alkaline soil (Beetle 1955; Rogler 1973). The species is particularly well suited for reclamation of disturbed sites and soil stabilization. In trials conducted in Wyoming and Montana, Western wheatgrass was one of the most promising of 174 grass, forb, and shrub species tested for reclaiming saline seeps and other problem sites (Scheetz and others 1981). In Nebraska, the grass has recently demonstrated the potential for controlling wind erosion in sand blowouts (Malakouti and others 1978).

The cultivars 'Barton,' 'Rosana,' 'Arriba,' and 'Flintlock' were released in the 1970s and helped alleviate seed shortage problems. Two new cultviars released in 1983 are:

'Rodan'

This cultivar was cooperatively released in 1983 by the USDA-ARS Northern Great Plains Research Center at Mandan, North Dakota, the USDA-SCS, and the North Dakota Agricultural Experiment Station. The parental germplasm was obtained from collections made in North Dakota. Selection was based primarily on vegetative vigor, forage quality, and rust reistance. It was originally tested as Mandan 456 and is considered to be an upland drought resistant type (Barker, R. E., Unpublished).

'Walsh'

This 20-clone synthetic cultivar was developed by the Agriculture Canada Research Station at Lethbridge, Alberta, and was released in 1983. It is apparently adapted to heavy clay soils and is tolerant of drought and salinity. Parental germplasm was selected on the basis of high forage and seed yield, aggressive rhizomes, and resistance to diseases. 'Walsh' is the first Western wheatgrass cultivar to be released in Canada (Smoliak and Johnston[3/]).

BLUEBUNCH WHEATGRASS Elytrigia spicata

Bluebunch wheatgrass, a cool-season, perennial bunchgrass, has long been considered one of the most valuable native grasses in the Intermountain region and Pacific Northwest. It is closely related to beardless wheatgrass. Dewey[4/] includes both grasses in Et. spicata. Bluebunch wheatgrass has excellent forage quality and often is preferentially grazed over other species in mixed stands. Because stands of this species are often depleted under heavy or untimely grazing, proper management is especially critical to maintain productive stands (Asay and Knowles[2/]; Hafenrichter and others 1968).

The cultivar 'Whitmar,' a beardless form released in 1946 has been widely used in revegetation programs (Wolfe and Morrison 1957). One new cultivar has been reported:

'Secar'

This cultivar was recently released by the USDA-SCS in cooperation with the Agricultural Experiment Stations of Washington, Oregon, Idaho, Montana, and Wyoming. The original germplasm was obtained from native stands near Lewiston, Idaho. The name 'Secar', which in Spanish means dry, was chosen to reflect the

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[2/]Asay, K. H.; Knowles, R. P. Ch. 18. In: Barnes, R. G.; Metcalfe, D. S.; Heath, M. E., eds. Forages - the science of grassland agriculture. 4th Edition. The Iowa State University Press, Ames. In Press.

[3/]Smoliak, S.; Johnston, A. Walsh western wheatgrass. Can. J. Plant Sci.: In Press; 1983.

[4/]Dewey, D. R. Historical and current taxonomic perspectives of Agropyron, Elymus, and related genera. Crop Sci. 23: In Press; 1983.

drought resistance of the cultivar. It is a densely tufted bunchgrass, with abundant, narrow leaves, fine stems, relatively small seeds, and divergent awns. It is adapted to the lower elevations of the Pacific Northwest and is reportedly persistent under adverse conditions. 'Secar' has been superior to 'Whitmar' in nearly all trials conducted in areas receiving less than 14 in (350 mm) of annual precipitation (Morrison and Kelley 1981).

THICKSPIKE WHEATGRASS Elymus lanceolatus

This sod-forming grass, which is native to North America, has been widely used for soil stabilization on disturbed range sites and other dry areas subject to erosion. When used for grazing, it provides a valuable source of forage during the summer when grasses such as crested wheatgrass are past their productive and nutritional peaks. Although it is morphologically similar to Western wheatgrass, thickspike wheatgrass is more drought resistant and less productive. It is so similar to streambank wheatgrass, both genetically and morphologically, that Dewey[4/] classified them as the same species. Dewey considered streambank wheatgrass to be the glabrous form of thickspike wheatgrass.

'Sodar' streambank wheatgrass and 'Critana' thickspike wheatgrass were released in 1954 and 1971, respectively. Both have been widely used as special-purpose grasses for stabilizing disturbed and eroded range sites (Stroh and others 1972; Douglas and Ensign 1954). One new cultivar is available:

'Elbee'

This cultivar of thickspike wheatgrass was developed by the Agriculture Canada Research Station at Lethbridge, Alberta. It was the first cultivar of thickspike wheatgrass (called northern wheatgrass in Canada) to be released in that country. The cultivar is noted for its excellent seed germination, and vigorous seedlings, resistance to drought, moderate rhizome development, and early spring growth. the original collections, from which the cultivar was derived, were made from the plains regions of Alberta and Saskatchewan (Smoliak and Johnston 1980a).

INTERSPECIFIC HYBRIDS

Over 250 different interspecific and intergeneric hybrid combinations have been developed by the USDA-ARS Cytogenetics Program at Logan. Many of these have limited agronomic merit and most are highly sterile. However, colchicine treatment and selection have yielded some promising breeding populations. These include: quackgrass (Elytrigia repens) X bluebunch wheatgrass, quackgrass X Standard crested wheatgrass, quackgrass X induced tetraploid 'Fairway' crested wheatgrass, bluebunch wheatgrass X thickspike wheatgrass, Altai wildrye X basin wildrye and mammoth wildrye, and Elytrigia acuta X intermediate wheatgrass.

The best of these appears to be the quackgrass X bluebunch wheatgrass hybrid (RS hybrid). The initial cross was made by D. R. Dewey in 1962. The F_1 generation produced very little seed, had poor vegetative vigor, and chlorophyll defective plants were prevalent. After eight cycles of selection, a breeding population with characteristics of both parental species has been obtained. The chromosome number has stabilized at 2n=42 and the hybrid is as fertile as either of the parental species. It is best adapted to the 12-18 in (300-450 mm) precipitation zone and in preliminary trials, has shown a surprising tolerance to saline conditions. The hybrid has responded particularly well to repeated clipping or grazing and has displayed exceptional palatability in animal grazing trials. Degree of vegetative spread (rhizome development) is under genetic control and can be successfully altered through selection. Rhizome development ranges from essentially bunch-type to a moderate degree of vegetative spread in the breeding population.

A major objective of the breeding program now is to eliminate undesirable segregates (off-types) that appear in each generation. Two germplasms, designated 'RS-1' and 'RS-2,' were released to other plant breeders and plant scientists in 1980 (Asay and Dewey 1981). Seed-increase blocks consisting of selected F_9 lines (9th generation after the initial cross) were established in 1982. Breeders seed for a possible cultivar release will be produced from these nurseries in 1983.

The quackgrass X Standard crested wheatgrass hybrid has also demonstrated sufficient potential to merit continued breeding work. This hybrid is not as genetically stable as the RS populations and sterility problems are still evident. However, trends indicate that continued selection will yield a fertile new species. A major goal is to develop strains that retain their forage quality longer during the summer months than presently available crested wheatgrass cultivars. Selection for the drought resistance of the crested wheatgrass parent and a moderate degree of rhizome development will also be emphasized.

Although the F_1 generation of the quackgrass X 'Fairway' crested wheatgrass hybrid is highly sterile, it may prove valuable for soil stabilization on problem sites such as mine spoils, roadsides, or rough-turf applications. Because it does not produce seed, vegetative propagation would be necessary. However, limited results from evaluation trials indicate that the hybrid lends itself well to this method of establishment on a limited acreage basis.

The bluebunch wheatgrass X thickspike and *Elytrigia acuta* X intermediate wheatgrass hybrids have performed well on range sites disturbed by surface mining operations. Although these populations are responding favorably to selection, it appears that additional breeding will be needed to achieve the seed fertility and genetic stability necessary for cultivar release.

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LEGUMES -- THEIR USE IN WILDLAND PLANTINGS

M. D. Rumbaugh

ABSTRACT: The inclusion of adapted legumes in wildland plantings has many benefits. Improved forage yield, quality, and seasonal distribution result in increased carrying capacity for livestock and game animals. Five primary criteria for selection of species to be used in wildlands are (1) availability of plants or seeds, and inoculum, (2) ease of establishment, (3) forage quality, (4) compatibility with associated species, and (5) persistence. Secondary criteria include (6) nitrogen fixation activity, (7) lateral spread by stolons, rhizomes, or roots, (8) seasonal distribution of forage, and (9) suitability for soil conservation, stabilization, or reclamation. Alfalfa (*Medicago sativa* and *M. falcata*) and biennial sweetclover (*Melilotus alba* and *M. officinalis*) have been used in wildland plantings more often than other legumes. Many other species should be considered for certain sites and uses.

VARIATION AND ADAPTATION OF LEGUMES

The legume family (Leguminosae) contains more species than any other plant family except for the grasses (Gramineae) and the orchids (Orchidaceae). There are at least 500 genera of legumes with approximately 15,000 species distributed world-wide. Certain genera, such as *Astragalus*, contain numerous and extremely diverse species. There are 849 species of that genus native to the Soviet Union (Borisova and others 1946), nearly 550 in North America (Hermann 1966), and 174 in Utah (USDA Soil Conservation Service 1978). Morphological variation within the Leguminosae ranges from large perennial trees (e.g. *Gleditsia triacanthus* - Honeylocust) to shrubs (e.g. *Prosopis glandulosa* - mesquite) and annual herbs (e.g. *Crotolaria spectabilis* - rattlebox). Adaptation varies from tropical jungles to deserts and arctic mountains. Only the grasses exceed legumes in economic importance and there is no shortage of genetic diversity within the Leguminosae. Suitable species exist for all types of wildland plantings.

The criteria for selecting legumes for inclusion in wildland plantings are few and simple. Five are of primary concern. (1) Availability of seeds or plants and of the *Rhizobium* inoculum is the first problem usually encountered. Often cultivars or species are recommended for use by scientists with slight consideration of the practical question of whether or not seed can be purchased. (2) The ease of establishment and (3) compatibility with other species are very important factors. Some legumes are inherently easier to establish than others because the seedlings are more vigorous and competitive than the seedlings of less well adapted species. (4) Quality of forage is a major concern since some species cause bloat, some contain toxic alkaloids or nitro compounds, and some are accumulators of selenium. (5) Persistence of perennials or the ability of annuals and biennials to reseed often is more important than the quantity of forage produced. Plant characteristics to be considered but of lesser consequence are the nitrogen fixation activity; lateral spread by rhizomes, stolons, or roots; the seasonal distribution of forage; and suitability for soil conservation, stabilization, or reclamation.

NITROGEN FIXATION

Although the nitrogen fixation activity of legumes is of less importance than some other attributes, it is a unique process and will be considered prior to discussing individual species. Many plants other than legumes possess mechanisms for nitrogen fixation but the quantity of nitrogen fixed is much less than that fixed by the legume host-*Rhizobium* symbiotic mechanism.

Inadequate supplies of plant-available nitrogen frequently limit forage production on western rangelands. Nitrogen deficiency has been estimated to reduce plant growth on 178 million acres (72 million hectares) of rangeland in the Northern Great Plains alone (Wight 1976). Nitrogen fertilization increased herbage yields 32 to 114 percent in average or near-average precipitation years and 218 percent during above-average precipitation years when evaluated over a 10-year period. These yield increases occurred without major species compositional changes in the native vegetation (Wight and Black 1979). Increased yields and better herbage quality resulted from nitrogen fertilization of more arid rangelands in the Great Basin even in a year when soil moisture was exceptionally low (James and Jurinak 1978). However, application of fertilizer to rangelands is expensive. Once established, an adapted legume species under proper management can continue to add fixed atmospheric nitrogen to the range site on a sustained basis without the recurring cost of annual fertilization.

M. D. Rumbaugh is Research Geneticist at the Crops Research Laboratory, USDA Agricultural Research Service, Utah State University, UMC-63, Logan, UT.

Native legumes often are active nitrogen fixing species when present on rangelands. In a study of central North American grasslands, native species of Amorpha, Cassia, Lespedeza, Psoralea, and Schrankia actively fixed atmospheric nitrogen (Becker and Crockett 1976). Species which occupied niches in pioneer through late seral stages of succession had a greater nitrogen-fixing capacity than species more limited to the climax. Symbiotic fixation in grasslands at the Jornada (desert grassland in southern New Mexico), Pawnee (shortgrass prairie in northeastern Colorado), Cottonwood (mixed prairie of western South Dakota), Pantex (shortgrass prairie of northern Texas), and Osage (tallgrass prairie in central Oklahoma) research sites has been shown to be small (Copley and Reuss 1972; Woodmansee 1979). Yet several lupine species actively fixed nitrogen in northern Utah and legumes growing in annual grasslands of California added significant amounts of nitrogen to the soil-plant system (Johnson and Rumbaugh 1981; Jones and Woodmansee 1979). Astragalus lentiginosus, Dalea fremontii, and Lupinus argenteus fixed nitrogen in the desert of southern Nevada (Farnsworth and others 1976). Even in the Colorado desert near Palm Desert, California, native legumes of the genera Astragalus, Dalea, Lotus, Lupinus, and Prosopis have been found to be nodulated and to fix nitrogen (Eskew and Ting 1978).

The preponderance of evidence indicates that native legumes are capable of nitrogen fixation during at least a part of their growing season. Where they have been eliminated by overgrazing, the range site is not receiving the benefit of the nitrogen that should be there by the legume mediated fixation process. Reintroducing the native species or replacing them with improved strains of other adapted legumes should assist in restoring the site to full productivity. Only a relatively few legume species have been used extensively for that purpose.

ALFALFA

Alfalfa (Medicago sativa and M. falcata) has been included in more range seeding projects in North America than any other legume. The genus Medicago is not native to the western hemisphere. It evolved in the Mediterranean region but the perennial forms of most interest for wildland use arose in western and central Asia (Lesins and Lesins 1979). The potential value of alfalfa for rangeland improvement in North America was first expressed by a horticulturist, Dr. N. E. Hansen of South Dakota (1913). In an address delivered in 1911 to the State Conservation and Development and Dry Farming Congress held at Pierre, South Dakota, Hansen said, "If we could clothe our naked hillsides with these wild Siberian alfalfas we could increase their present carrying capacity for stock seven to eight times." Hansen's concepts were sharply defined by 1913 when he wrote, "These alfalfas and clovers may be used in two ways: (1) As a cultivated crop for hay and pasture, and (2) to introduce as wild plants into the native ranges of the Prairie Northwest, where they will probably be able to hold their own with any plant now found there."

Experimental attempts to establish alfalfa in existing grass stands by sod seeding were initiated at Highmore, South Dakota, as early as 1909 (Oakley and Garver 1917). It was also at Highmore that Samuel Garver discovered plants in one of Hansen's Russian introductions that had extensive, spreading lateral root systems. That characteristic has since been incorporated through breeding into a number of range and pasture alfalfa cultivars (Rumbaugh 1979, 1982a). Canadian scientists assumed an early and commanding lead in the breeding and use of alfalfa for grazing (Heinrichs 1963). A few ranchers also realized its potential and pioneered methods to establish alfalfa in native vegetation (Miles 1969).

Despite the risk of stand failure in adverse environments, range managers recommend the use of alfalfa for range improvement projects more frequently than any other legume (Gomm 1974; Kneebone 1959; Rumbaugh and Thorne 1965; Townsend and others 1975; Vallentine and others 1963). Alfalfa is known to persist well once it is established (Rumbaugh and Pedersen 1979; Wilton and others 1978). It is also capable of reproduction and self-perpetuation through natural reseeding on sites with as little as 11 inches (28 cm) annual precipitation (Rumbaugh 1982b). Preliminary data indicate that alfalfa can fix nitrogen during periods of drought stress when other legume species are not nodulated or are not active (Johnson and Rumbaugh 1981). When alfalfa is well established in game ranges, it effectively keeps game animals on those ranges and helps prevent their invading cultivated fields (Plummer and others 1968). The introduction of the dryland cultivar 'Nomad' proved to be one of the most successful techniques used to improve antelope (Antilocapra americana) ranges in southeastern Oregon (Yoakum 1979). After 36 separate aerial seedings on more than 56,000 acres (22,000 ha), alfalfa constituted 10 percent of the vegetation present for 6 years or longer. More antelope does with fawns were observed on these seedings than on adjacent shrub-dominated rangelands.

Gains in forage yield as a result of establishing legumes depend on site characteristics, precipitation, the legume species, interactions with associated species, and relative stand densities. Rumbaugh (unpublished data) measured forage yields of 14-year-old stands on a 14 inch (35 cm) annual precipitation shortgrass range in Harding County, South Dakota. Sod seeded alfalfa plots produced 253 percent as much total forage as untreated check plots. In a more complex experiment involving grass, shrub, and legume components growing at Nephi, Utah, significant increases in forage yields were attained through the use of alfalfa and other

legumes (Rumbaugh and others 1981, 1982). Crested wheatgrass (Agropyron desertorum) produced 183 percent as much grass foliage when grown with legumes as grass grown without legumes. In addition, the alfalfa plants contributed directly in a major way to a higher total forage yield.

Protein concentrations of grasses also increase when grown in association with legumes. In the experiment at Nephi previously cited, transect segments containing only grass had forage with 5.5 percent protein when averaged over four harvests. Segments where both grass and alfalfa were growing produced grass forage with 6.2 percent protein. In addition, the alfalfa foliage had twice the protein concentration of the grass on each of the four sampling dates. Both the quantity and the quality of the grass improved because of the association with alfalfa. The legume also appeared to cause the crested wheatgrass to recover more rapidly after clipping. Grass grown with alfalfa produced twice as much forage a year after it was first harvested as did grass grown without alfalfa. Again, the alfalfa also contributed directly and importantly to total regrowth forage. Alfalfa was easily established on Idaho fescue (Festuca idahoensis), bluebunch wheatgrass (Agropyron spicatum), western wheatgrass (A. smithii), junegrass (Koeleria cristata) range by a combination of close grazing and tillage or close grazing and broadcasting seed into frost cracks (Miles 1969). It thrived and established colonies of plants on dry wind swept sites at 5,000 feet (1 500 m) elevation where soils contained sufficient lime. A short period of intense grazing during May and June was considered more favorable management for alfalfa than a long period of summer grazing.

SWEETCLOVER

Sweetclover occurs sporadically throughout the United States as a pioneer plant on disturbed sites. The two species most frequently encountered are Melilotus alba (white-flowered) and M. officinalis (yellow-flowered). There are annual and biennial forms of each, but most populations are biennial (Smith and Gorz 1965). Both species grow rapidly, are deep-rooted, are excellent seed producers, and fix nitrogen very well when properly inoculated with suitable Rhizobium bacteria. Heavy stands are common along roadsides and in gullies where a supply of seed has accumulated in the soil and where moisture collected (Plummer and others 1968).

Sweetclover ranks next to alfalfa in frequency of use for improvement of perennial ranges. However, there is less information about its value than for alfalfa. Yellow-blossom sweetclover seeded with A. desertorum in Montana produced more forage than either the grass or legume seeded alone (Gomm 1964). The crude protein content of sweetclover forage in that study exceeded the content in alfalfa. Protein content of grass grown with either legume species was higher than when grown in a pure stand. Sweetclover also performed very well on a dense clay range site in western South Dakota that had been severely depleted by drought and overgrazing (Nichols and Johnson 1969). After being seeded in 1962 without seedbed preparation, yellow-blossom sweetclover reseeded naturally and remained a compatable associate with the native vegetation during the 5-year study. Combined grass and sweetclover forage production averaged 1,804 lb/acre (2 022 kg/ha) annually compared to 750 lb/acre (840 kg/ha) for the control treatment. The grass component was increased by 373 lb/acre (418 kg/ha) as a result of legume supplied nitrogen. Western wheatgrass (Agropyron smithii) vigor and protein content were also improved. Native perennial grasses were not reduced in abundance by sweetclover competition.

Volunteer yellow-blossom sweetclover produced more than 450 lb/acre (500 kg/ha) seed on a Montana rangeland receiving an average of 20 inches (50 cm) annual precipitation and located at 4,700-7,000 feet (1 400 to 2 100 m) elevation (Miles 1970). Stand maintenance was not a problem once the sweetclover was well established on south facing slopes. It was observed to grow but, because of undetermined factors, not to reseed on north facing slopes. The most effective method of introduction was to broadcast seed after burning the limber pine (Pinus flexilis) and big sagebrush (Artemisia tridentata). Without site preparation, the few plants that were established produced little seed because of close grazing by deer. With the large amount of sweetclover which resulted from seeding after burning, the deer were confronted with more legume growth than they could keep from going to seed. Second-year sweetclover itself was highly competitive to sweetclover seedlings. To obtain the best forage utilization and seed production, pasturing was initiated prior to bloom stage and stopped when the plants had been grazed to a 10 inch (25 cm) stubble. The sweetclover then regrew and produced an abundance of seed. The same management procedure probably could be used elsewhere with other adapted range legumes.

As a wildland species in the Intermountain Area, sweetclover maintains itself best on favorable sites of the mountain brush and pinyon-juniper zones but its contribution to forage yield has not been documented (Plummer and others 1968). In addition to being a valuable forage plant, sweetclovers are important species for honey production and their seeds are of some value to upland gamebirds (Hermann 1966). Dwarf forms are known and the merit of breeding rapidly growing and early maturing cultivars of short stature for droughty sites should be explored.

CLOVERS

True clovers belong to the genus Trifolium. Most species require an annual precipitation in excess of 20 inches (50 cm) in order to do well and no species native to North America has been used extensively for range improvement. Introduced species have been used extensively throughout the United States. More research has been conducted with Trifolium species on California rangelands than elsewhere and the use of clover has been very successful (Williams and others 1956). The seeding of adapted species and phosphate fertilization accompanied by appropriate management increased the grazing capacity three-fold in one experiment lasting five years. Use of a mixture of annual clovers of varying growth habit was suggested as it allowed a much greater latitude in adjustment of stock use than was possible with a single species. Clovers most often used for improvement of these annual rangelands are rose clover (T. hirtum), crimson clover (T. incarnatum), and subterranean clover (T. subterraneum).

In southeastern United States rangelands, growing white clover (T. repens) with any of the five major perennial forage grasses was found to increase the protein concentration in the resulting forage all season long (Dobson and Beaty 1980). Grass forages grown with the clover averaged as high or higher in protein as monospecific grass forage fertilized at nitrogen rates up to 300 lb/acre (336 kg/ha). The inclusion of clover also significantly increased the calcium concentration of the forage compared to the grass alone. Biologically, growing a legume such as white clover on southern ranges probably offers more opportunity to increase forage nutritional yield and quality than any other practice generally available. This also may be true of high elevation western ranges receiving sufficient precipitation to support growth of Trifolium species.

There are three relatively unknown clovers that merit attention as candidates for potential use on higher elevation western rangelands. These are T. amabile, T. ambiguum, and T. rubens. All have certain deficiencies such as poor seedling vigor but it may be possible to overcome them through breeding or management. Trifolium amabile is indigenous to Andean rangelands at elevations between 9,500 and 12,800 feet (2 900 and 3 900 m). It is a more vigorous and productive perennial than many of our native high elevation clovers such as the T. beckwithii of the Intermountain Region. Little research has been done with this species and only a few germplasm accessions are available to plant breeders. However, it grows well at Logan, Utah, at an elevation of 4,500 feet (1 400 m) and its value for mountain meadow and mountain grassland seeding should be tested.

Kura clover (T. ambiguum) has been investigated previously in the United States but has not achieved prominance as a forage crop (Kannenberg and Elliott 1962; Keim 1954). It is a cold-hardy, drought tolerant, rhizomatous perennial which is also resistant to several virus diseases which attack other clovers (Barnett and Gibson 1975). However, early experiences with this species resulted in stand failure because of weak seedlings and a lack of nodulation. Until quite recently, only a few germplasm accessions were available in the United States and sufficient genetic diversity was not present to permit plant breeders to correct these problems (Townsend 1970).

Researchers in Australia and New Zealand have been more successful. Kura clover was first introduced into Australia in 1931, but testing did not proceed beyond the nursery stage until the mid 1950's when naturally occurring ploidy groups were recognized (Bryant 1974; Hely 1972). It also became possible to differentiate between alpine and cold continental ecotypes (Costin and Wimbush 1963). The nature of resistance to nodulation was first identified and then selection for improved nodulation began (Hely 1963, 1971). Two cultivars were released by CSIRO in 1972 (Barnard 1972). One was a diploid, 'Summit', and the other a tetraploid, 'Treeline'. Other cultivars, some of which are hexaploids, have since been developed. The hexaploid forms are reputedly adapted to grassy steppes, spread well, and are persistent and productive. Kura clover maintained its stand density in a year of drought stress that almost eliminated white clover (Spencer and others 1975). This probably was because of its extensive root and rhizome system. Kura clover had four times as much underground biomass as white clover and approximately one-third of it consisted of rhizomes.

As a consequence of recent plant collections in the Soviet Union by D. R. Dewey and A. P. Plummer, United States breeders now have available an adequate representation of the genetic diversity of T. ambiguum to successfully develop improved populations for wildland use (Dewey and Plummer 1980). Four year old plants of that collection growing in a spaced-plant nursery at Logan, Utah, had an average crown diameter of 30 inches (73.4 cm), were 12 inches (30.5 cm) in height, and had 49 heads per square foot (530 heads per m^2). Superior clones of this species were selected and progeny trials initiated.

The Dewey and Plummer collection also contained one accession of T. rubens. Only one prior introduction of this species, sometimes called foxtail clover, has been available in the United States. I know of no current agronomic research with T. rubens, yet in many ways it is an attractive clover. Plants grown at Logan, Utah, were perennial, winterhardy, tall, erect, and productive of both forage and seed. Individual plants yielded as much as 1.2 ounces (33 g) of seed. Since T. rubens evolved in the submontane xerothermic areas of submediterranean middle

Europe, it may possess attributes of hardiness and drought resistance of value in wildlands of the Intermountain Region (Hendrych 1970). Despite the lack of seedling vigor (N. L. Taylor, personal communication) and the restricted germplasm base available, we have initiated a selection and evalution program with this species.

SWEETVETCH

One species of sweetvetch, Hedysarum coronarium, has achieved prominence as a forage crop in countries bordering the Mediterranean and in parts of Australia (Duke and Reed 1981). Known as sulla or sulla sweetvetch, H. coronarium is either fed as fresh forage or as hay or is used as a green manure crop to improve soil fertility and tilth. Sulla is reported to tolerate annual precipitation of 18 to 93 inches (46 to 236 cm), annual temperatures of 42° to 83°F (5.7° to 29.9°C), and to range from the Boreal Moist through the Tropical Forest Life Zones. H. mongolicum and H. scoparium have received some attention in China as species suited for range improvement and for stabilization of sand dunes (Min in press). Seeds of these two species have been available to scientists in the United States only within the last year. Seed increase and research with them and with H. coronarium has been initiated in Utah and Montana.

The native Utah sweetvetch, H. boreale, is regarded as a valuable wildland legume (Kneebone 1959; Plummer and others 1968). Sweetvetch starts growth early in the spring, produces abundant forage, and some basal leaves remain green throughout the winter. The foliage is highly palatable to big game and livestock. The species is a good seed producer and is well suited to cultivation for that purpose. H. boreale also may be vegetatively propagated and transplanted to sites where direct seeding is not possible or is not desirable (Institute for Land Rehabilitation 1979). Sweetvetch strains differ in rhizome development, plant size, seedling vigor, disease resistance, and seed yield. Populations in our breeding program at Logan, Utah, have been advanced into a second cycle of recurrent selection based on these traits. Utah sweetvetch and all other Hedysarum species tested, contained condensed tannins and therefore are thought to be bloat-safe legumes (M. D. Rumbaugh, unpublished).

MILKVETCH

The genus Astragalus to which the milkvetches belong is an extremely diverse and interesting group of plants. It also is a group which presents many problems for ranchers. More than 500 species are native to North America (Hermann 1966). These can be divided into classes according to their effects on animals: (1) those that are acutely toxic, (2) those that are chronically toxic, (3) those that cause the locoweed syndrome, (4) those that are toxic due to their selenium content, and (5) a class that is nontoxic (James and Johnson 1976). None of these species have been exploited for range improvement work. Two introduced Asiatic species have been used in wildland plantings.

Astragalus falcatus, sicklepod milkvetch, is a very productive legume from the Soviet Union and is well adapted to favorable areas of the pinyon-juniper and big sagebrush ranges (Plummer and others 1968). It is a large plant that often protrudes above the snow to provide winter feed. The inclusion of sicklepod milkvetch with crested wheatgrass in a planting at Nephi, Utah, increased both the forage and protein yields of the grass (Rumbaugh and others 1981, 1982). This species has the additional advantage that it is easier to establish than several other legumes with which it has been compared (Townsend and McGinnies 1972). However, A. falcatus foliage is known to contain high levels of nitro compounds and it should be classified as a poisonous plant (Williams and others 1976). Therefore, this species should not be introduced into additional wildland sites unless strains are discovered which are not toxic to animals.

Astragalus cicer, cicer milkvetch, is entirely safe for grazing and has been used more extensively in North America than any other member of this genus. Breeding work with cicer is underway in Colorado and Alberta and several improved cultivars have been released (Townsend and others 1975; Townsend 1981). Relatively low seedling vigor has restricted the use of this species as a forage plant (Townsend and Wilson 1981). Cicer is bloat safe and is known to be better adapted to sandy soil than to loam soil. It does best at locations receiving more than 15 inches (40 cm) annual precipitation. On a droughty site in Utah, cicer had lower forage and protein yields than either sicklepod milkvetch or alfalfa (Rumbaugh and others 1981, 1982). More information about this species should be obtained from longer term and larger plantings. Its use in wildland improvement projects should be encouraged.

SAINFOIN

Sainfoin, Onobrychis viciifolia, is an attractive legume with many characteristics desirable for wildland use. It is nonbloating, relatively easy to establish, and productive of forage and seed (Townsend and others 1975). Sainfoin is a deep-rooted perennial with a tap root that can extend to a depth of 3 to 30 feet (1 to 10 m) (Ditterline and Cooper 1975). It also is reported to be winterhardy, drought resistant, and long lived although significant losses of sainfoin stands during 4- and 5-year test periods in Colorado and in central Montana have been observed (Dubbs 1971; Townsend and others 1975).

Sainfoin performed better where it was seeded alone in range scalping and interseeding studies

in Montana than where it was seeded with a grass (Ryerson and Taylor 1968). However, none of the stands were considered satisfactory. The competitive ability of the sainfoin seedlings was considered to be questionable under range conditions although the species seemed to be able to maintain itself and to spread into a mixed vegetational cover once it was established. The researchers suggested that information on the following points was needed before wide use of sainfoin on rangeland could be recommended.

1. Performance (productivity and longevity) in large scale interseedings.

2. Comparison with other legumes under range conditions.

3. Performance under seasonal grazing on range.

4. Animal response to sainfoin-interseeded range.

5. Methods of controlling undesirable plants in established sainfoin interseedings.

6. Watershed and wildlife relationships of sainfoin in range interseedings.

7. Overall effects on multiple-use management of private and public lands.

Few of these problems have been addressed in a significant way since the list was formulated in 1968. One important study took place in Turkey during 1969-1975 (Tosun and others 1977). A replicated grazing experiment with sheep was conducted on 12-acre (5-ha) plots Hay yields of native range, alfalfa plus grass, and sainfoin plus grass treatments were 0.93, 2.02, and 1.82 tons/acre (1.047, 2.264, and 2.040 metric tons/ha). The resulting live weight gains of sheep were 21.0, 56.3, and 51.8 lb/acre (23.5, 63.1, and 58.1 kg/ha) for native range, alfalfa plus grass, and sainfoin plus grass plots. After an appropriate economic analysis, profits from each of the legume treatments exceeded 300 percent of that for the untreated native range.

OTHER LEGUMES

Many species of herbaceous legumes other than those already discussed have been considered by plant scientists for wildland projects. These include native or introduced members of the following genera: Amorpha, Baptisia, Chamaecrista, Coronilla, Dalea, Desmanthus, Indigofera, Lathyrus, Lespedeza, Lotus, Lupinus, Medicago, Petalostemum, Shrankia, Sphaerophysa, Strophostyles, Tephrosia, and Vicia. Undoubtedly there are others not listed here. Most often these species have not been used extensively because they lack seedling vigor and consequently are difficult to establish or they are poor seed producers. In some instances suitable Rhizobium cultures have not been available. More rarely, research with a vigorous species was halted because of fear that the legume would prove to be a weedy pest.

CONCLUSIONS

The world plant community has provided several herbaceous legumes of proven value for wildland plantings. Their use should be extended by range managers in a position to do so. These species frequently improve the quantity, quality, and seasonal distribution of forage resulting in an increase in carrying capacity and profitability of rangelands. They fix significant quantities of atmospheric nitrogen which ultimately is used by associated grasses. Most legumes are beneficial for wildlife as well as livestock. Some excel in lesser ways as effective species for soil conservation, mine soil reclamation, honey production, and site beautification.

Lesser known species are being improved by plant breeders. As this germplasm becomes available, range scientists are encouraged to evaluate it, document its advantages and disadvantages, and appraise the originators of their findings. Through cooperative efforts, more legumes will find a home on western wildlands. As one knowledgeable and articulate rancher from Montana wrote, "It has been frequently said: 'Suitable range legumes haven't been found.' Seems it should read: 'Suitable range legumes for existing management systems haven't been found'" (Miles 1969).

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NONLEGUMINOUS FORBS FOR RANGELAND SITES

Nancy Shaw and Stephen B. Monsen

ABSTRACT: Adapted native and introduced nonleguminous forbs may be selected to increase the value and diversity of range seedings. Forb use in range restoration has been limited by erratic seed crops and high seed costs. Initial releases and improved cultural techniques have contributed to increases in the species and quantities of forb seeds marketed and planted annually.

INTRODUCTION

Native nonleguminous forbs are common in most plant communities of the Intermountain region. They may grow mixed with grasses and other forbs, as an understory to trees and shrubs, or infrequently as pure stands. Individual species may be adapted to several vegetative types and distributed over a wide geographic range or may exhibit specific site requirements. Ecotypes differing in morphological or physiological characteristics have developed within many species.

Selected native and introduced forbs are valuable additions to rangeland plantings:

1. They increase the diversity of the plant community, permitting it to support a wider range of organisms.

2. They provide high quality forage and may seasonally supply critical nutrients and succulence for game animals and livestock, particularly domestic sheep. Fruits, seeds, and leaves of forbs are frequently a principal food of upland gamebirds.

3. Spreading varieties may be used to control erosion and provide ground cover on unstable sites.

4. Low-maintenance landscaping for roadsides, rest areas, and campgrounds is enhanced by the inclusion of forb species that flower at different seasons and produce attractive foliage.

5. Forbs that remain green through the summer or winter months may serve to extend the grazing season and increase the fire resistance of plantings.

6. Selected species are useful as pioneer species or nurse crops on disturbed sites.

With the exception of small burnet, nonleguminous forbs have received limited use in range improvement projects due to low seed availability and high costs. At present, most seed is hand collected from wildland stands. Seed crops are dependent upon weather conditions and are subject to grazing, insect attacks, and disease, and as a result are quite erratic. Seed collection of many species is complicated by indeterminate flowering and seed set. Most forbs normally grow intermixed with other species and only rarely occur in more easily collected pure stands. Nearly pure stands of some species, such as arrowleaf balsamroot (*Balsamorhiza sagittata*) and gooseberryleaf globemallow (*Sphaeralcea grossulariaefolia*), are occasionally found growing on nearly level terrain and can be combine harvested. As a result of difficulties encountered in gathering and cleaning native forb seed, collectors tend to select only those species and ecotypes that are easily handled. Management of local stands of frequently used species or ecotypes for seed production may be a means of assuring and increasing annual seed crops of adapted sources.

During recent years, the USDA Soil Conservation Service has placed increased emphasis on the development of improved lines of native forbs. Collections from throughout the geographic range of selected species are being examined and tested in outplanting trials to determine their range of adaptability and uniformity in reproducing specific combinations of desirable characteristics. Cultural techniques for propagating these species in seed fields and rangeland seedings are being developed (Redente and others 1982; Wasser 1982). Only a limited number of nonleguminous forb releases--'Appar' Lewis flax (*Linum lewisii*), 'Bandera' Rocky Mountain penstemon (*Penstemon strictus*), and 'Delar' small burnet (*Sanguisorba minor*)--are available for use in the Intermountain area (USDA, SCS 1982), although further releases are scheduled. Growers are beginning to produce seed of additional species from seed of selected wildland collections.

Table 1 lists 29 forb species and information relating to their use and value in rangeland seedings. Forage value, palatability, and season and degree of use of individual forbs by various classes of livestock and wildlife have been reported or reviewed by a number of authors (USDA Forest Service 1937; Yoakum 1958; Gullion 1966; Hermann 1966; Plummer and others 1968; Kufeld 1973; Kufeld and others 1973; Institute for Land Rehabilitation Staff 1978; Smith and Beale 1980; Wasser 1982).

Nancy Shaw and Stephen B. Monsen are Botanist and Botanist/Biologist, respectively, at the Forestry Sciences Laboratory, USDA Forest Service, Intermountain Forest and Range Experiment Station, Boise, Idaho.

Table 1.--Characteristics of major forb species used in rangeland plantings

Species	Vegetation type[1]	Soil stabilization value[2]	Root system	Structure planted	Seed processing and planting consideration[3]	Seeding method[4]	Acceptable purity (percent)[5]	No. seeds per pound[5]	Storage period (years)[5,6]
Achillea millefolium lanulosa	2,3,4,5,6,7,8	4	Fibrous, rhizomatous	Achene	1	2,1,6,3	50	4,123,635	
Artemisia ludoviciana	3,4,5,6,7,8	5	Fibrous, rhizomatous	Achene	1	2,1,6,3	80[7]	3,800,000[7]	
Aster chilensis adscendens	3,4,5,6,7,8	5	Fibrous, rhizomatous	Narrow achene	1,5	2,1,6,3	40	2,668,235	4-6
Aster glaucodes	4,5,6,7,8	5	Fibrous, rhizomatous	Narrow achene	1,5	2,1,6,3	40	540,000	4-6
Balsamorhiza sagittata	3,4,5,6,7	1	Thick taproot	Large achene	2,4	4,6,3	95	55,245	4
Balsamorhiza macrophylla	4,5,6,7	1	Thick taproot	Large achene	2,4	4,6,3	95	32,220	3
Erigeron speciosus	8	2	Taproot, rhizomatous	Achene	1,5	2,1,3,6			
Geranium viscosissimum	4,6,7,8	3	Taproot, rhizomatous	Seed	1	5,6,2	95	52,550	7-10
Helianthella uniflora	4,6,7	2	Taproot	Achene	3	3,6,2,1	60	53,560	4-6
Heracleum lanatum	6,7,8 (moist areas)	2	Taproot or cluster of fibrous roots	Elongate mericarp	2,3	4,6,3,2,1	85	44,850	3
Ligusticum porteri	6,7,8	3	Taproot (fibrous root crown)	Elongate mericarp	2,3	4,6,3,2,1	90	69,275	5
Linum lewisii	1,2,3,4,5,6,7	2	Taproot	Seed	1,2	2,1,3,6	90	278,280	7-10
Lomatium nutallii	4,5,6,7,8	2	Tuberous roots	Elongate, winged mericarp	2,3	4,3,6,2	75	42,225	4
Lomatium triternatum	5,6,7,8	2	Taproot	Winged mericarp	2,3	4,3,6,2	75		
Mertensia sp.	4,5,6,7,8	3	Rhizomatous, thick tuberous roots or taproots	Nutlet	2	3,5,6,2			
Osmorhiza occidentalis	6,7,8	1	Thick fascicled roots	Elongate mericarp	2,3	4,6,3	95	29,845	4-6
Penstemon cyananthus	4,5,6	4	Taproot	Seed	1	3,2,6,1,5	95	234,785	7-10
Penstemon eatonii	3,4,5,6,7	3	Taproot	Seed	1	3,2,6,1,5	95	351,085	7-10
Penstemon humilus	3,4,5,6	4	Fibrous, rhizomatous	Seed	1	3,2,6,1,5	95		7-10
Penstemon palmeri	2,3,4,5,6	3	Fibrous	Seed	1	3,2,6,1,5	95	609,675	15

(con.)

Table 1.--(con.)

Species	Vegetation type[1]	Soil stabilization value[2]	Root system	Structure planted	Seed processing and planting consideration[3]	Seeding method[4]	Acceptable purity (percent)[5]	No. seeds per pound[5]	Storage period (years)[5,6]
Penstemon strictus	4,5,6,7	4	Fibrous, rhizomatous	Seed	1	3,2,6,1,5			
Sanguisorba minor	2,3,4,5,6	3	Taproot, rhizomatous	Achene		3,2,1,6	95	55,115	15
Senecio serra	6,7,8	4	Fibrous	Achene	1,5	3,2,6,1	50	3,489,230	0-3
Solidago canadensis	6,7,8	4	Fibrous, rhizomatous	Achene	1,5	2,1,4,6,3	50		0-3
Sphaeralcea coccinea	1,2,3,4,5	3	Taproot, rhizomatous	Schizocarp	2	3,6,2,1	90		16+
Sphaeralcea grossulariaefolia	1,2,3,4,5,6	2	Taproot	Schizocarp	2	3,6,2,1	90	500,660	15
Tragopogon porrifolius	2,3,4,5	2	Taproot	Achene	2,3	4,2,6,1,3	85	306,695	4-6
Valeriana edulis	7,8	3	Fibrous, rhizomatous	Achene	1	5,3,6,2			
Viguiera multiflora	3,4,5,6,7	3	Branched taproot	Achene	1,5	2,3,6,5	50	1,054,885	4-6
Viguiera multiflora nevadensis	2,3,4,5	3	Branched taproot	Achene	1,5	2,3,6,5	50		4-6

[1]Vegetative types:
1. Salt desert shrublands
2. Wyoming big sagebrush
3. Basin big sagebrush
4. Mountain big sagebrush
5. Pinyon-juniper
6. Mountain brush
7. Aspen
8. Subalpine herblands

[2]Soil stabilization value:
1. Low
2. Fair
3. Moderate
4. Good
5. High

[3]Seed processing and planting considerations:
1. Small seed (>500,000/lb).
2. Fall or winter seeding required.
3. Seed may be broken or damaged during processing or seeding.
4. Low seed fill or insect predation of seeds common.
5. Seed difficult to clean to high purity.

[4]Seeding method:
1. Aerial broadcast and cover. Seed of other species may be successfully seeded by this technique, but is rarely available in adequate quantities.
2. Broadcast and cover - hand or ground equipment.
3. Drill with seed mixture.
4. Drill separately - same depth as grasses. Includes species which are slow to develop, do not compete well with most grasses or for which seed is normally in short supply.
5. Drill separately - shallow depth. Same as no. 4, but very small seeded species.
6. Cultipack separately or in mixtures.

[5]Acceptable purity - purchased seed should be cleaned to at least the indicated level. Jorgensen, K. R. Ephraim, UT: Data on file at Great Basin Experimental Range, Intermountain Forest and Range Experiment Station; 1983.

[6]Stevens and others (1981a).

[7]Stranathan, Sam. Meeker, CO: Data on file at Upper Colorado Environmental Plant Center; 1982.

MAJOR NONLEGUMINOUS FORBS USED IN RANGELAND SEEDINGS

Small Burnet

There are approximately 30 species of burnet (Sanguisorba), occurring primarily in Europe and the Middle East (Hermann 1966). Two species, western burnet (S. occidentalis) and Alaskan Burnet (S. sitchensis), which are native to western North America, are locally valued as forage plants (Hermann 1966; Hitchcock and others 1961). Selections of small burnet from Mediterranean and Middle Eastern countries are more widely adapted to sites in the Intermountain region than any of the native species. Small burnet grows well in heavy clay to sandy loam soils (Plummer 1977) and is suited to the sagebrush, blackbrush, and pinyon-juniper types and drier sites in the mountain brush zone (Plummer and others 1968; Howard 1981).

Small burnet is a short-lived, perennial forb that persists from 7 to 12 years. However, survival in some Utah plantings has exceeded 20 years (Plummer and others 1968). Plants consist of a basal rosette of pinnately compound leaves arising from a caudex and taproot. Numerous flowering stalks may grow from 2 to 20 inches (5 to 50 cm) in height. Flowers are formed in dense, terminal heads. The evergreen plants are reasonably fire-resistant and are used throughout the year by game, livestock, rodents, and rabbits (Plummer and others 1968; Howard 1981). Small burnet is particularly important in late winter, early spring, and late summer when other species provide little green forage. Stand vigor and density may be reduced by selective grazing during these periods. Good seed crops are generally produced, but may be consumed by rodents if their populations are high (Everett and others 1978; Stevens[1]). Reproduction will occur if sufficient seed is left.

Excellent seed production, high seed quality, and ease of seed processing and planting have contributed to the widespread use of small burnet. It can be broadcast or drill seeded in mixtures with best results being obtained following fall or winter seedings (Stevens and others 1981b). Vegetative propagation can be accomplished by dividing and transplanting the somewhat rhizomatous plants. Introduction of S. magnollii, S. dictyocarpum, and S. muricata have exhibited characteristics similar to those of S. minor when grown on southwestern Idaho rangelands.[2]

'Delar' small burnet was released in 1979 by the USDA Soil Conservation Service, Plant Materials Center, Aberdeen, Idaho. It is recommended for sites in the Intermountain region that receive at least 12 inches (30 cm) of annual precipitation. Under irrigation Delar has produced up to 1,050 lbs of seed per acre (1 178 kg/ha) (Howard 1981).

[1]Stevens, R. Ephraim, UT: Data on file at Great Basin Experimental Area; 1982.

[2]Shaw, N. Boise, ID: Data on file at Forestry Sciences Laboratory; 1978-83.

Lewis Flax

The genus Linum consists of approximately 100 species and is distributed world-wide, primarily in the temperate regions (Hitchcock and others 1961). About 20 species occur in the western United States (Hermann 1966). Lewis flax was discovered by Meriwether Lewis near the Continental Divide in Montana (USDA Forest Service 1937). This widely distributed perennial forb ranges from Alaska and Saskatchewan to California and Texas (Davis 1952; Harrington 1964). It grows on well-drained soils from salt desert shrub communities to ridges and openings in the mountain brush, conifer, and aspen types at elevations of up to 10,000 ft (3 050 m) (USDA Forest Service 1937; Plummer and others 1968).

Lewis flax is a short-lived forb with a longevity of 5 to 7 years (Howard and Jorgensen 1980). Numerous glabrous stems are produced from a woody taproot. Plants average 0.3 to 2.3 ft (0.1 to 0.7 m) in height, but may grow to 3 ft (0.9 m) with irrigation (Hitchcock and others 1961; Howard and Jorgensen 1980). Although not highly productive, Lewis flax initiates growth early in the spring and is used by livestock and wildlife (Stevens see footnote 1). It is generally highly palatable and tolerant of grazing. Stems dry during the summer, but basal leaves may remain green and are utilized throughout the year (USDA Forest Service 1937; Plummer and others 1968). Seeds are consumed by rodents and birds (Everett and others 1978; Howard and Jorgensen 1980).

Flowering is indeterminate, beginning in mid-May and continuing for approximately 6 weeks (Plummer and others 1968). The attractive flowers are blue to white, opening in the morning and closing by afternoon. The petals are caducous, generally abscissing within 1 day of flowering (Addicott 1977). Because of its prolonged flowering period and colorful flowers, Lewis flax has been seeded alone or in mixtures in roadway plantings and landscaping projects.

The capsules of Lewis flax contain numerous seeds and mature over several weeks during late summer and early fall. Wildland stands are hand harvested while agricultural seed fields are combined. Seed is easily cleaned. After-ripening may be required to obtain maximum germination (Eddleman 1977). Stevens and others (1981a) found Lewis flax to maintain a viability of 70 percent after storage for 10 years in an open warehouse. Lewis flax has been successfully seeded in range, wildlife habitat, roadways, mine disturbance, and landscape plantings. Seed may be broadcast, drilled, or interseeded during the late fall or winter months (Stevens and others 1981b). The vigorous seedlings develop rapidly and are compatible with grasses, shrubs, and other forbs when planted in mixtures (Plummer and others 1968; Plummer and others 1970; McKenzie and others 1980). Lewis flax persists well through natural reseeding. It has been one of the most successful forbs used in aerial seedings on pinyon-juniper sites. DePuit

and Coenenberg (1979) and DePuit and others (1980) found Lewis flax to establish better than other forbs tested on coal mine spoils at Rosebud, Mont. Wildings, bareroot or container seedlings, or mature plants may be transplanted on disturbed sites to quickly establish a source of seed (Plummer and others 1968).

In 1980, 'Appar' Lewis flax was released by the USDA Forest Service, Intermountain Forest and Range Experiment Station; USDA Soil Conservation Service, Aberdeen Plant Materials Center; and the Utah Division of Wildlife Resources. This cultivar was named for A. Perry Plummer who selected it from native stands in the Black Hills of South Dakota for its appearance and competitiveness with native grasses. It is easily grown under agricultural conditions and has produced up to 700 lbs of seed per acre (786 kg/ha) with irrigation. Appar exhibits wide adaptability to sites in the Intermountain region and is nontoxic. It is recommended for areas receiving from 10 to 23 inches (25 to 58 cm) of annual precipitation (Howard and Jorgensen 1980).

Louisiana Sagebrush

Louisiana sagebrush (Artemisia ludoviciana) is distributed throughout western North America and occurs east to Illinois an Arkansas (Hitchcock and other 1955; Harrington 1964). It is found on dry, open sites from the sagebrush to the alpine zones. The subspecies and numerous ecotypes vary widely in stem height, leaf color and shape, seed production, degree of rhizomatous spread, and geographic distribution. Louisiana sagebrush grows rapidly and is normally long-lived and drought and cold tolerant. Although its forage value is not rated highly, it is used by domestic sheep, mule deer, and other game animals and may be seasonally important in their diets (Hermann 1966; McCulloch 1973). Monsen (1975) and Monsen and Plummer (1978) found Louisiana sagebrush to be an early invader of infertile dredge mine disturbances in central Idaho. Seed or sprigs have been used to plant roadway, logging, and other disturbances in this area. Sprigs spread rapidly on these sites producing crown diameters of up to 3 ft (1 m) in diameter and dense masses of rhizomes and fibrous roots during the first year.[3] Although Louisiana sagebrush quickly provides excellent soil cover and stabilization, it serves as a nurse crop, permitting the establishment and development of other species that may eventually dominate the site.

The acenes of Louisiana sagebrush are tiny, without appendages, and there are approximately 3,800,000 per lb (8,360,000/kg).[4] They are collected by hand harvesting or combining. As with other sages, viability of Louisiana sage seed declines when stored for more than 2 to 3 years.[5] Seed may be planted separately or in mixtures by drill, aerial, or broadcast seeding during the fall or winter. A number of promising collections are being tested for possible release by the Upper Colorado Environmental Plant Center, Meeker, Colo., and the Intermountain Forest and Range Experiment Station for use in the reclamation of mined lands and other disturbances in the Intermountain and Rocky Mountain regions.

Penstemon

Many of the more than 200 species of penstemon (Penstemon) are native to western North America (USDA Forest Service 1937; Hitchcock 1959; Hermann 1966). Penstemons occur in most vegetative types; occasionally as nearly pure stands. Most are short-lived herbaceous species that spread well from seed. A number of species produce evergreen basal leaves that are used by game and livestock during all seasons. Rhizomatously spreading species are easily established from seed or transplants and are useful for soil stabilization. Many of these species naturally colonize disturbances. Penstemons are frequently used to add diversity and color to landscape plantings.

Date of seed collection varies with species and geographic location. Capsules may be stripped from the plants by hand or with a reel-type harvester or combine. Seeds are small, easily cleaned, and usually exhibit high germination, although stratification and fall planting may be required to release the seed dormancy of some species (McDonough 1969; Wasser 1982). Penstemons also compete well with grasses and herbs and can be seeded in mixtures by drilling or broadcast seeding. If drill seeded, the equipment should be carefully adjusted to prevent planting the seeds too deep.

Bandera Rocky Mountain penstemon was released by the Agricultural Experiment Stations of New Mexico State University and Colorado State University, the New Mexico State Highway Department, and the USDA Soil Conservation Service Plant Material Center, Los Lunas, N. Mex. (Wolfe and others 1982). It is a leafy perennial with a basal rosette of leaves that may grow to a diameter of 30 inches (75 cm); it has showy blue to violet flowers and a fibrous root system. Bandera is recommended for ornamental landscaping and soil stabilization, and it provides diversity when seeded in mixtures on roadways, mines, and rangelands. Seed or sprigs may be used to establish it on rocky to sand loams in areas receiving 15 to 20 inches (38 to 51 cm) of annual precipitation and at elevations ranging from 6,000 to 11,000 ft (1 850 to 3 355 m). It is recommended for adapted sites from central New Mexico to southern Wyoming and west to central Utah.

[3]Monsen, S. B. Boise, ID: Data on file at Forestry Sciences Laboratory; 1974-82.
[4]Stranathan, S. Meeker, CO: Upper Colorado Environmental Plant Center; 1982.

[5]Jorgensen, K. R. Ephraim, UT: Data on file at Great Basin Experimental Area; 1982.

Palmer penstemon (Penstemon palmeri) is native to basic, neutral, or acidic soils in southern Utah, Nevada, Arizona, and California at elevations ranging from 3,500 to 6,000 ft (1 070 to 1 830 m) (Plummer 1977; Thornberg 1982). It is distributed through the sagebrush, blackbrush, and pinyon-juniper, and mountain brush zones and quickly invades disturbances within these areas. This short-lived (4 to 5 years) drought-tolerant species spreads readily from seed (Stevens, see footnote 1). The basal rosette of grey-green leaves remains succulent year round. Roots are thick and fibrous. Flowering stalks are abundant and grow to 3 ft (1 m) in height. Showy pink flowers blossom over several weeks. The species provides year-round forage for deer, elk, antelope, and sheep, receiving greatest use in the winter and spring (Plummer and others 1955; Smith and Beale 1980). It is an outstanding ornamental and provides moderate soil stabilization on disturbances in arid areas. Abundant seed production and ease of hand collection from wildland stands have contributed to its widespread use. Some seed is now being commercially produced in seed fields. A selection from the Cedar City, Utah, area is scheduled for release in 1984 by the Utah Division of Wildlife Resources, the Intermountain Forest and Range Experiment Station, and the USDA Soil Conservation Service.

Aster

Approximately 250 species of the genus Aster are distributed worldwide primarily in the temperate regions (Hitchcock and others 1955). Sixty species are native to western North America (Hermann 1966). They are found on nearly all soil types and in most plant communities. Native asters generally occur mixed with other species and seldom form extensive pure stands. Species vary widely in range of adaptation, forage value, palatability, and soil stabilization potential. Kufeld and others (1973) listed 10 species that received light to moderate summer use by mule deer and variable use during the remainder of the year. Clary an Kruse (1979) found A. commutatus to be a preferred deer forage in central Arizona during dry summers when summer annuals failed to appear. Moderate to heavy use of various Aster species by elk and seasonal use by sheep and antelope were reported by Kufeld (1973), Buchanan and others (1972), and Smith and Beale (1980).

Pacific aster (Aster chilensis adscendens) is a long-lived rhizomatous forb found throughout the Intermountain region. It exhibits a wide range of adaptability, occurring in the sagebrush, mountain brush, and aspen types. It also occurs on such diverse sites as inland saltgrass communities, wet meadows, and exposed slopes at high elevations. Plants provide early spring forage for elk, deer, and livestock, and are used during all seasons. Palatability varies widely among populations. The species spreads vegetatively as well as by seed. Monsen and Plummer (1978) report that it is a pioneer species on dredge mined sites in Idaho and recommend its use on roadcuts and fills, mine spoils, and other disturbances.

Seeds of Pacific aster are gathered by hand from wildland stands during the fall. The pappus is removed from the fruits by debearding. Seed is frequently sold at purities of 20 to 60 percent. Germinability of new seed is generally high, but viability declines if seeds are stored for more than 3 years under warehouse conditions (Stevens and others 1981a). Seed may be aerial or broadcast or drill seeded. It may also be drill seeded if it is planted at a shallow depth. Pacific aster establishes well when planted alone or in mixtures. Seedlings are vigorous, grow rapidly and flower by the second year (Stevens and others 1981b), providing good initial ground cover on disturbed sites. Root sections are easily divided and transplanted (Plummer and others 1968).

Globemallow

Of the approximately 200 species of globemallow, 20 are native to the western United States. These drought-tolerant perennial forbs grow mixed with other species from salt desert shrub sites to dry foothills in sagebrush and pinyon-juniper types (USDA Forest Service 1937; Plummer and others 1968).

Gooseberryleaf globemallow ranges from central Idaho to south-central Washington and south to Utah and Nevada (Hitchcock and others 1961). It is a densely pubescent perennial forb with ascending branches developing to 2.3 ft (0.7 m) in height from a stout taproot (Hitchcock and others 1961). It is common in the blackbrush, salt desert shrub, sagebrush, and pinyon-juniper and mountain brush types (Plummer and others 1968). Gooseberryleaf globemallow provides fair to excellent forage for antelope (Smith and Beale 1980). Kufeld (1973) reported that it receives moderate fall use by mule deer. Urness and McCullock (1973) found it to form part of the winter and early spring diet of the Three Bar mule deer herd in central Arizona. Measurements of protein content varied from 10 to 20 percent during this period. Forage value is low to good for livestock (Hermann 1966). Gooseberryleaf globemallow and related species are useful for revegetation projects in arid areas as they are common invaders of disturbances. Plants quickly become established, grow to maturity, and spread by seed. They are valuable, low-maintenance ornamentals, producing numerous bright orange flowers over an extended period.

Gooseberryleaf globemallow seed matures unevenly and is generally collected by hand in July or August. A reel-type harvester may be used where unusually dense stands are found. Seeds are easily cleaned and have remained viable for 16 years in warehouse storage (Stevens and others 1981a). Fruits are small, averaging 500,000 mericarps per lb (1,100,000/kg) (Plummer and others 1968). Page and others (1966) found the characteristically low germination to result from a combination of low fill and hard seed coats impregnated with nonwettable substances. Gooseberryleaf globemallow may be seeded in

mixtures in the fall or winter by broadcast or drill seeding (Monsen and Plummer 1978). It can also be transplanted as wildings or containerized seedlings produced from seed or stem cuttings (Plummer and others 1968).

Scarlet globemallow (S. coccinea) occurs from Alberta and Manitoba to northeastern Arizona, Texas, and western Iowa (Harrington 1964; Hermann 1966). Its drought tolerance and ability to spread rhizomatously make it particularly useful for plantings on disturbances in arid areas (Stevens, see footnote 1).

Balsamroot

Twelve species of balsamroot occur in western North America (Hermann 1966). The name refers to the thickened resinous taproot that may grow to several inches in diameter and 6 ft (2 m) in length (Spence 1937; USDA Forest Service 1937). Arrowleaf balsamroot is the most abundant and widely distributed species, ranging from west of the Sierra Nevada and Cascade summits to British Columbia and east to Saskatchewan and South Dakota (Hitchcock and others 1955; Hermann 1966). It exhibits a wide range of adaptation and may be found growing on well-drained acid to alkaline soils from basin big sagebrush communities to open ridges and south and west aspects in aspen and ponderosa pine types. Scattered plants are found in more arid communities.

Arrowleaf balsamroot is a long-lived perennial forb. Basal clusters of coarse grey to silvery sagittate leaves develop from the thick taproot. Flowers are solitary on stalks of up to 2 ft (0.7 m) in length. Plants are highly productive, initiating growth and flowering early in the spring. During this period, foliage and seed heads are utilized by elk, deer, bighorn sheep, antelope, and other game animals, as well as by cattle and particularly domestic sheep (Kufeld 1973; Kufeld and others 1973; Monsen and Plummer 1978; Smith and Beale 1980; Harniss and Wright 1982; Holechek and others 1982). Palatability and use of the species varies geographically.

The foliage dries early in the summer, but a few basal leaves may remain green through late summer in moist areas (Stevens, see footnote 1). Dry foliage and seed heads are consumed throughout the year (Trout and Thiessen 1973; Kufeld 1973; Kufeld and others 1973). The deep taproot system provides tolerance to drought, trampling, and grazing. However, as spread is entirely by seed, heavy grazing will reduce the number of seedlings. The deep taproot and low initial growth rate provide only moderate soil stabilization value (Spence 1937; Plummer 1968).

Seed is collected from May to July by hand or with a reel-type harvester or combine. Large quantities of seed are normally produced, however, seed crops are frequently lost to insects, wildlife, livestock, or frost, and seed viability is frequently low as a result of insect damage. Seed yields of stands designed for seed collection would be significantly increased by protection from grazing or insect control measures. Stevens and others (1981a) found that the seed may be stored under warehouse conditions for 4 to 5 years. Arrowleaf balsamroot may be broadcast or drill seeded. Drilling it in separate rows from other species in the mix serves to reduce competition, maximizing growth and survival. Fall or winter plantings are recommended as Young and Evans (1979) found that a 3-month stratification of 0° C is required to break seed dormancy. Seed should be covered to prevent losses to rodents. Compared to other commonly seeded species, Everett and others (1978) found the seed of arrowleaf balsamroot to be highly preferred by deer mice.

Seedlings of arrowleaf balsamroot are persistent when seeded on adapted sites and are compatible with other species when planted in mixtures. However, the plants develop slowly and do not provide good cover or forage for 5 to 10 years following planting. Seedlings of arrowleaf balsamroot are not easily transplanted (Plummer and others 1968).

Other species of Balsamorhiza exhibit characteristics similar to arrowleaf balsamroot, but are more limited in distribution. Most are used early in the spring, but palatability varies among species and ecotypes. Cutleaf balsamroot (B. macrophylla) is often planted at higher elevations and under more moist conditions than arrowleaf balsamroot. Hairy balsamroot (B. hirsuta) develops much more rapidly than other species, but is usually limited to the understory of mountain brush communities.

CONCLUSIONS

Nonleguminous forbs may be seeded to improve diversity, forage production, length of growing season, aesthetics and soil stability of rangeland sites. Forbs may be selected from species and ecotypes indigenous to the planting area. Management of local stands may be required to insure the production of adequate quantities of seed. Alternatively, seed of improved varieties of an increasing number of commonly used species are being grown in agricultural fields with more reliable seed supplies resulting. Nurseries are propagating transplant stock of a wide array of species from seed or cuttings for use when site stabilization, aesthetic improvements, or the rapid establishment of a seed source are required.

Advances in seed collection and processing, improved propagation techniques, and increased knowledge of seed germination requirements have evolved from recent research, forb selection programs, and agricultural production of forb seed. Further advances in the use of forbs for rangeland restoration require improved seed quality and understanding of seeding requirements, and seedling emergence and establishment. Careful attention to interaction of forbs with other species and microsite conditions and their response to use is needed to facilitate management of seeded stands.

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SOME PROMISING CHENOPODS FOR USE ON DISTURBED LANDS

Howard C. Stutz

ABSTRACT: Some of the harshest sites in western North America are occupied solely by members of the family Chenopodiaceae. Because of the abundant genetic variation present in many of the species, there is good opportunity for deliberate breeding and selection of superior forms. This is particularly true of Atriplex which has experienced an explosive evolution during recent years, yielding numerous forms uniquely adapted to specific sites.

INTRODUCTION

Thousands of acres of salt desert in western North America are occupied solely by plants belonging to the family Chenopodiaceae. In some places the Chenopod landscape is small -- on the order of one hundred acres (40 ha) or less. More often it is so extensive that one can travel all day by automobile without seeing anything but Chenopods. In total, more than 300 million acres (120 million ha) in western North America are dominated by these remarkable plants.

The reasons for the superior performance of Chenopods are not well known but must include attributes which permit accommodation of both climatological drought resulting from low levels of precipitation, and physiological drought caused by high salt content of soils. Some species excrete salt externally on the surface of leaves (Osmond and others 1980; Mozafar and Gooden 1970; Hill and Hill 1976). Some adjust by increasing succulence (Black 1958). Some species circumvent challenges by becoming dormant during periods of stress. Some apparently obtain physiological advantages from saline environments (Ashley and Beadle 1957; Caldwell 1974).

There are seven principal genera of perennial Chenopods in western North America: Atriplex, Ceratoides, Grayia, Kochia, Sarcobatus, Suaeda and Zuckia.

Genus	Species
Atriplex	more than 20 named species and at least that many more to be yet named
Ceratoides	C. lanata
Grayia	G. brandegei, G. spinosa
Kochia	K. americana
Sarcobatus	S. vermiculatus, S. baileyi
Suaeda	S. fruticosa
Zuckia	Z. arizonica

Howard C. Stutz is Professor of Botany and Genetics in the Department of Botany and Range Science, Brigham Young University, Provo, Utah.

Of these, Atriplex is the only one in which there has been an explosive eruption of species. Each of the other genera only have one or two species as follows:

CERATOIDES

C. lanata (winterfat) is a highly variable species but primarily at the genic level; all, so far examined, are diploid except one population of tetraploids in central Colorado. Winterfat grows throughout all of western North America from Alaska to Mexico. Some forms grow to more than three feet (one meter); most are less than one foot (30 cm) tall.

Because of its extensive genetic variation, potential for improvement by breeding is very promising.

GRAYIA

G. brandegei is narrowly distributed in southern Wyoming, western Colorado, southeastern Utah and northeastern Arizona. It is found almost exclusively on talus and steep mud slopes. Variations in stature and leaf size are dramatic but no genetic studies have yet been made to disclose the bases for these or other differences. So far, only diploid chromosome numbers have been found.

Grayia brandegei is very different from G. spinosa but very much like Zuckia arizonica and therefore would probably best be changed to Z. brandegei.

G. spinosa (Hook.) Moq. (Spiny Hop-sage) is an important range plant throughout much of Utah, Nevada, Colorado, Idaho, Wyoming and eastern parts of California, Oregon and Washington. Variations expressed between natural populations suggest promise for improvements by breeding and selection.

KOCHIA

K. americana Wats. (Green Molly) is usually considered to be the only perennial species of Kochia in North America although some authors recognize K. californica as a distinct species with smaller leaves and more spreading habit. K. americana occupies extremely harsh environments which are usually dry and alkaline. It is apparently quite uniform genetically and hence not amenable to much improvement by genetic manipulation.

SARCOBATUS

S. baileyi Cov. grows only in western Nevada and east-central Utah. It is generally not listed as an important range plant but because of its capacity to accommodate severely harsh environments, it deserves more consideration. It occurs in almost pure stands, sometimes covering thousands of acres, on dry gravelly soils. It appears to express very little genetic variation so may be unsuited for much genetic improvement.

S. vermiculatus (Hook.) Torr. (Greasewood) is a highly variable species growing mostly in bottomlands in heavy clay soils but often extends up even steep hillsides, particularly where there is seepage and/or saline soils. It is endemic to western United States and Canada. It is most abundant in the Great Basin but extends northward to southern Alberta and eastern Oregon and Washington, and southward to Arizona and Texas. Two chromosome races (4N and 8N) have been detected thus far but have not been shown to be correlated with morphology nor ecological preference. Although generally considered a nuisance plant in some areas, it is sometimes highly prized for forage, particularly where it is associated with other species which provide dietary variety.

SUAEDA

S. fruticosa (L.) Forsk (seepweed) is common in moist saline bottomlands throughout western North America from Alberta to Mexico and also throughout much of Europe and the Middle East. Some authors have referred to the American form as S. torreyana Wats., but there appears to be no consistent differences which will delineate it from the old world form. There is considerable variation within the species, particularly in habit and in edaphic restrictions. Most plants are 15-30 inches (38-76 cm) at maturity but some have been reported at more than 6 feet (2 meters) in height, while other populations consist of plants which are no more than 8 inches (20 cm) in height. Most grow on heavy clay soils but many populations occur on sands.

Very little attention has been given to the genetics of Suaeda but because of its abundance inherent genetic variation, it should be possible to prepare genotypes which would be suitable for use on many range sites.

ZUCKIA

Z. arizonica Standl. has until recently been thought to be endemic to northwestern Arizona but it is also common in many parts of Utah. It has apparently escaped attention because of its superficial resemblance to Grayia brandegei. It has also been collected and deposited in herbaria as Atriplex. However it is a very distinctive species and because of its tolerance of extremely harsh environments deserves our attention. It is found mostly on shallow sandy soils as scattered, widely spaced bushes with very little else growing with it. It appears to be genetically quite uniform so probably offers little promise for development for use on other sites.

ATRIPLEX

Atriplex is so genetically rich and evolutionarily explosive, it is difficult to become acquainted with the component species except within an evolutionary and genealogical context. Although much is yet to be studied before a completely valid interpretation can be formulated, it is possible, from what we do know to identify some highly probable biogeographical history to accommodate most of the recognizable variations.

It appears that during the Pleistocene, Atriplex canescens (four-wing saltbush) existed in the diploid form throughout much of the southern Mojave and northern Sonoran deserts. Tetraploids were most common east of the Rockies in what was probably an ice free corridor. Following the demise of Pleistocene Lakes 10-12,000 years ago, tetraploid forms derived from the warm desert diploids migrated northward into the Great Basin and other intermountain terrain. This northward migration is apparently still in progress and can be witnessed at several advancing fronts. It (4N A, canescens) has arrived at Pocatello, Idaho but not at Blackfoot nor Idaho Falls. It has marched to the Snake River near Boise, Idaho but has only rarely crossed it. It is at Marsing, Idaho and Ontario, Oregon, but not yet to Weiser.

These tetraploids which have just recently migrated northward to occupy much of New Mexico, Arizona, Utah, Nevada, California, southern Oregon, southern Idaho and western Colorado appear to be genetically distinct from the more ancient forms which reside east of the Rockies.

During their northward migration, A. canescens came in contact with other Atriplex species with which it has hybridized to produce numerous new adaptive products which are now expanding to fill unique habitats. Among the most fruitful of these interspecific hybrids have been A. canescens x A. tridentata, A. canescens x A. falcata and A. canescens x A. polycarpa.

A. canescens east of the Rockies hybridized with A. gardneri to give an array of hybrid products collectively referred to as A. aptera ("Wytana" saltbush is one of these products).

Another important species which has had phenomenal success since the disappearance of the Pleistocene lakes is A. confertifolia (shadscale). During the Pleistocene it apparently existed in the diploid form throughout much of the Intermountain West, above the lakes and northeast of the montane glaciers in ice-free tablelands. With the disappearance of the lakes, tetraploid forms derived from the resident diploids spread into the empty valleys as immense

monoculture populations, occupying the vast domains left exposed as the waters receded. Octoploids and decaploids followed, also occupying extensive acreages left exposed as the lakes dried up.

Hybridization of A. confertifolia and A. canescens has provided introgressant populations having improved genetic capabilities but no distinct taxon has yet been found.

While A. canescens was migrating from the south and A. confertifolia was expanding into newly exposed domains, a battery of other Atriplex taxa were entering this same arena from the north. A. canadensis sp. nov., a common diploid species in Alberta and Saskatchewan, apparently gave rise to at least three other distinct taxa: A. falcata, A. gardneri and A. tridentata. Each of these grade almost imperceptably into A. canadensis but separate neatly into distinct entities as they move further and further south.

A. falcata occurs mainly as a diploid form throughout southern and eastern Oregon, southern Idaho, southern Wyoming, western Utah and much of Nevada. It usually occurs in monoculture populations of ca 5 to 30 acres (2 to 13 ha) on sandy loam soils. Sharp contact boundaries usually separate it from Artemisia tridentata, Ceratoides lanata, Sarcobatus vermiculatus or other species of Atriplex. Although mostly diploid, both tetraploid and hexaploid forms are also known.

A. gardneri is abundant throughout Wyoming, Montana, and North and South Dakota west of the Missouri River. It occurs mostly in the tetraploid form although diploids are quite common, particularly on harsher sites. Throughout much of its territory A. gardneri contacts and hybridizes with A. canescens yielding, in many instances, the hybrid derivative A. aptera.

A. tridentata occurs as diploids, tetraploids and hexaploids but it is only at the hexaploid level that it has been phenomonally successful. This is the form which occupies thousands of acres of the saline bottomlands of old Lake Bonneville. It is a vigorous root-sprouter which may account for some of its success in competing for these rich, albeit saline, territories. Its contact and subsequent hybridization with A. canescens has yielded several new exciting hybrid derivatives. Hybrids with A. confertifolia are also common, and although less conspicuous than those derived from hybridizing with A. canescens, may be responsible for some of its extensive variation and also perhaps for some of the variation found in A. confertifolia.

Besides this evolutionarily explosive eruption of Atriplex in the Great Basin brought about by the intermingling and hybridization of taxa which recently migrated in from both the north and the south, together with those which were already resident, other forms have evolved elsewhere in western North America. In the Colorado River drainage of eastern Utah and western Colorado a number of unique diploid species have combined in various combinations to produce new highly adaptive taxa. Also chromosome races of many species have emerged in response to major ecological variations.

In eastern Utah and western Colorado tetraploid Atriplex cuneata appears to have arisen several times as an allopolyploid from different combinations of various diploid species as well as an autopolyploid from A. ancestrale sp. nova. A. corrugata occurs here also in both diploid and tetraploid forms.

In the southern deserts, mostly south of 37° latitude, several other Atriplex species dominate many areas. A. obovata is common throughout Arizona, New Mexico, Chihuahua and Sonora. Although of lower palatability than most other species of Atriplex, it is a highly important range plant, partly because in many places it is almost the only species which can accommodate the harsh, warm, saline deserts. In some respects it is the southern counterpart of A. tridentata to the north in that it is an upright subshrub, a vigorous root-sprouter and grows mostly in heavy clay soils.

Hybrids between A. obovata and A. canescens are not common but when they do occur, hybrid swarms and segregating backcross progeny are common. Some of these have proven to be very valuable in use on mine spoils in northern New Mexico.

A. polycarpa is one of the most drought tolerant of all Atriplex species. It is common throughout the Mojave Desert and down into many parts of Mexico including most of Baja California. Its interest to range managers to the north comes from its potential for increasing drought tolerance in cold tolerant species. In many places it hybridizes rather freely with A. canescens yielding fertile hybrids and hybrid segregants. An important derivative from these hybrids is A. laciniata, a remarkably promising species found in many places throughout the Mojave Desert.

There are several other important, well known species of Atriplex in western North America and they too demonstrate the unusual propensity for rapid evolution and hence the promise for almost unlimited opportunity for improvement through breeding and selection. Because most species of Atriplex are available in several chromosome races, readily hybridize with others upon contact and are mostly cross-pollinated, their genetic base is phenomonally rich. They are remarkably adapted to accommodate almost all of the existing challenges presented by the deserts of western north America and because of their rich genetic heritage can provide new permutations suitable for accommodating almost any conceivable new challenge. Probably no other group of plants could offer more potential for genetic manipulation.

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USE OF ROSACEOUS SHRUBS FOR WILDLAND PLANTINGS IN THE INTERMOUNTAIN WEST

Robert B. Ferguson

ABSTRACT: This paper summarizes information on Rosaceous shrubs to assist range or wildlife managers in planning range improvement projects. Species from at least 16 different genera of the Rosaceae family have been used, or are potentially useful, for revegetating disturbed wildlands in the Intermountain West. Information is given on form and rate of growth, reproduction, longevity, and geographical distribution of useful Rosaceous shrubs. Information is also presented on forage value, response to fire and herbicides, and the effects of insects and disease. Finally, methods used for the establishment of the Rosaceous shrubs are described.

INTRODUCTION

William A. Dayton (1931), early plant ecologist of the Forest Service, stated, "The rose group (Rosaceae) is, with the possible exception of the composites, the most widely developed shrub family in the west and all things considered, is perhaps the most important as range browse." Robinette (1972), citing Martin and others (1951), listed 18 genera of shrubs widely used for food and the numbers of wildlife species known to use them. The genera Rubus, Prunus, and Amelanchier ranked first, second, and seventh in that list, respectively.

Following World War II, range and wildlife managers in several Western States realized the need to increase the availability of browse on numerous deer winter range areas. In the 1950's and 1960's much of the research on artificial revegetation of depleted game ranges dealt with antelope bitterbrush (Purshia tridentata [Pursh] DC.). Holmgren (1956) noted that of several browse species adapted for survival on southwestern Idaho big game winter ranges, bitterbrush showed the most promise for range rehabilitation. He noted that attempts to establish bitterbrush in southwestern Idaho had been made almost every year since 1937. Research on bitterbrush was also carried out in California (Hubbard and others 1959), Oregon (Stanton 1959), Utah (Plummer and others 1957), and Washington (Brown and Martinsen 1959). Basile (1967) compiled an annotated bibliography of numerous bitterbrush studies to aid in research and management.

Robert B. Ferguson is Range Scientist at the Intermountain Forest and Range Experiment Station, Shrub Sciences Laboratory, USDA Forest Service, Provo, Utah.

While many of the early efforts to use shrub species in artificial revegetation centered on bitterbrush, other members of the Rosaceae were being studied and recommended. Plummer and others (1968) listed species that could be used in revegetation programs in Utah, including true mountain mahogany (Cercocarpus montanus Raf.), curlleaf mountain mahogany (C. ledifolius Nutt.), cliffrose (Cowania mexicana var. stansburiana [Torr.] Jeps.), desert bitterbrush (Purshia glandulosa Curran), Saskatoon serviceberry (Amelanchier alnifolia Nutt.), Utah serviceberry (A. utahensis Koehne), Woods rose (Rosa woodsii Lindl.), apache plume (Fallugia paradoxa [D. Don] Endl.), black chokecherry (Prunus virginiana L. var. melanocarpa [A. Nels.] Sarg.), desert peachbrush (P. fasciculata [Torr.] Gray), American plum (P. americana Marsh), squawapple (Peraphyllum ramosissimum Nutt.), and bush cinquefoil (Potentilla fruticosa L.). Holmgren (1954) listed curlleaf mountain mahogany, Saskatoon serviceberry, and black chokecherry, in addition to antelope bitterbrush, as potentially useful species on the Payette River deer winter range in Idaho. Brown and Martinsen (1959) concluded that antelope bitterbrush, black chokecherry, American plum, and Douglas hawthorn (Crataegus douglasii Lindl.) were the most promising of the native rosaceous shrubs for planting on big game winter range in Washington, with several other species of Prunus and one species of rose also recommended for dryland sites.

Since about 1946, the plant genera named above have been used more than any others in the rose family in attempts to revegetate depleted game ranges and other disturbed sites in the western United States. However, several other genera of the Rosaceae could be used to good advantage on specific sites, including Rubus, Sorbus, Spiraea, Holodiscus, Physocarpus, and Crataegus.

This paper summarizes information on these Rosaceous shrubs to assist the range or wildlife manager in planning range improvement projects. Because numerous plant names are mentioned, a list of scientific names, and associated common names, is given in table 1.

BOTANICAL CHARACTERISTICS

The shrubs of the rose family discussed herein all have five petals and five sepals, and alternate leaf arrangement. The flowers have numerous stamens and both male and female parts (except in some species of the genus Rubus that

Table 1.--Scientific and common names of plants mentioned in this paper.

Scientific name	Common name
Agropyron desertorum (Fisch.) Schult.	desert wheatgrass
Amelanchier alnifolia Nutt.	Saskatoon serviceberry
Amelanchier oreophila A. Nels.	mountain serviceberry
Amelanchier utahensis Koehne	Utah serviceberry
Bromus tectorum L.	cheatgrass
Cercocarpus intricatus S. Wats	littleleaf mountain mahogany
Cercocarpus ledifolius Nutt.	curlleaf mountain mahogany
Cercocarpus montanus Raf.	true mountain mahogany
Cowania mexicana var. stansburiana (Torr.) Jeps.	Cliffrose
Crataegus douglasii Lindl.	Douglas hawthorn
Fallugia paradoxa (D. Don) Endl.	apache plume
Holodiscus discolor (Pursh) Maxim	oceanspray
Holodiscus dumosus (Hook.) Heller	bush oceanspray
Malus seiboldi (Reg.) Rehd.	Toringo crabapple
Peraphyllum ramosissimum Nutt.	squawapple
Physocarpus alternans (Jones) T. J. Howell	dwarf ninebark
Physocarpus capitatus (Pursh) Kuntze	Pacific ninebark
Physocarpus intermedius (Rydb.) Schneid.	Illinois ninebark
Physocarpus malvaceous (Greene) Kuntze	mallow ninebark
Physocarpus monogynus (Torr.) Coult.	mountain ninebark
Potentilla fruticosa L.	bush cinquefoil
Prunus americana Marsh	American plum
Prunus andersonii Gray	Anderson peachbrush
Prunus besseyi Bailey	Bessey cherry
Prunus emarginata (Dougl.) Walp.	bittercherry
Prunus fasciculata (Torr.) Gray	desert peachbrush
Prunus munsoniana Bailey	wild goose plum
Prunus virginiana L. var. demissa (Nutt.)	western chokecherry
Prunus virginiana L. var. melanocarpa (A. Nels.) Sarg.	black chokecherry
Purshia glandulosa Curran	desert bitterbrush
Purshia tridentata (Pursh) DC.	antelope bitterbrush
Rosa acicularis Lindl.	prickly rose
Rosa arkansana Porter	Arkansas rose
Rosa gymnocarpa Nutt.	baldhip rose
Rosa nutkana Presl.	Nootka rose
Rosa woodsii Lindl.	Woods rose
Rubus leucodermis Dougl.	blackcap
Rubus parviflorus Nutt.	thimbleberry
Sorbus scopulina Greene	Greenes mountain ash
Sorbus sitchensis Roemer	Sitka mountain ash
Spiraea betulifolia Pall.	shiny-leaf spirea
Spiraea densiflora Nutt.	subalpine spirea
Spiraea douglasii Hook	Douglas spirea

have male and female flowers on separate plants). Table 2 gives additional information on flowers, fruit, leaves, height, and ecotypic variation.

Growth form varies from almost viney in some species of Rubus to small trees in serviceberry, chokecherry, bittercherry (Prunus emarginata [Dougl.] Walp.), hawthorn, and mountain ash (Sorbus). However, most species occur as multiple-stemmed shrubs, with some (bittercherry, spirea, and ninebark) forming dense clumps. In the genus Purshia some ecotypes of antelope bitterbrush are nearly prostrate, while others are entirely erect in form. The most useful of the wild roses also tend to exhibit an erect habit.

As seedlings, and often during the first 2 or 3 years of life, the rosaceous shrubs are slower growing than other plant species used in revegetation projects, such as many of the Chenopods and Composites. Curlleaf mountain mahogany exhibits rapid root elongation following seedling emergence--3.7 ft (1.1 m) in 4 months. The top, however, may reach a height of only 1 to 2 inches (2.5 to 5 cm) the first season (Dealy 1975). After becoming well established, growth of some species can be quite rapid on good sites. Medin and Ferguson (1980) observed current shoot lengths of 20 to 31 inches (50 to 80 cm) on many young antelope bitterbrush shrubs in southwestern Idaho in 1967.

The life span probably varies from 10 to 20 years for species of Rubus to over 150 years for curlleaf mountain mahogany, antelope bitterbrush, and cliffrose. Very little information on longevity is available in the

Table 2.--Some botanical characteristics of important genera of Rosaceae

	Flowers		Fruit	Leaves	Maximum height	Recognized ecotypes
Amelanchier	W	R	P	S,D	25'	Yes
Cercocarpus	--	S	A	S,D-E	25'	Yes
Cowania	W-Y	S	A	S,E	15'	Yes
Crataegus	W-Re	Co	P	S,D	35'	No
Fallugia	W	S	A	S,E	7'	No
Holodiscus	W	P	A	S,D	10'	No
Peraphyllum	W-Pi	S	P	S,D	7'	No
Physocarpus	W	Co	F	S,D	7'	No
Potentilla	Y	Cy	A	C,E	4'	No
Prunus	W	R	D	S,D	30'	Yes
Purshia	Y	S	A	S,D-E	13'	Yes
Rosa	Re-Ro	S-Cy	A	C,D	10'	Yes
Rubus	W	R-Cy	Ag	C,D	8'	No
Sorbus	W	Cy	P	C,D	20'	No
Spiraea	W-Re	P	F	S,D	8'	No

Key to botanical characteristics:

Flowers: Pi = pink, Re = red, Ro = rose, W = white, Y = yellow, Co = corymb, Cy = cyme, P = panicle, R = raceme, S = solitary

Fruit: A = achene, Ag = aggregate, D = drupe, F = follicle, P = pome

Leaves: C = compound, D = deciduous, E = evergreen, S = simple

literature. Nord (1959) reported a maximum age of 160 years for antelope bitterbrush in California. Brotherson and others (1980) found true mountain mahogany 54 years of age in samples taken in the Uintah Basin of Utah, and curlleaf mountain mahogany 168 years of age in a sampled population in central Utah. Scheldt and Tisdale (1970) reported that ages of curlleaf mountain mahogany in Idaho ranged up to 150 years, but that stems older than this had rotten cores that made accurate aging impossible.

With some notable exceptions most natural reproduction of the rosaceous shrubs is from seed. Seed size ranges from the very small seed of ninebark (Physocarpus), oceanspray (Holodiscus), and spirea (Spiraea) (millions per pound) to the stones of the species of cherries (2,000 to 7,000 per pound). Excellent information on seed characteristics is given in Schopmyer (1974). Although seeds of most of the larger-seeded species are palatable to rodents, these animals often aid plant establishment by burying seed in caches that provide sites for seed germination. This has been noted especially with antelope bitterbrush (Hormay 1943; Nord 1959; Stanton 1959; and Everett and Kulla 1976). Wild roses, bittercherry, the chokecherries, apache plume, and the spireas all spread by root suckers and can be found in dense clumps. Some ecotypes of antelope bitterbrush have been observed to layer when lower branches are covered with soil. Table 3 summarizes the vegetative reproduction habit of some rosaceous species.

Hybridization is common among species of the genera Purshia, Cercocarpus, Rosa, Amelanchier, and Crataegus. Stutz (1972) discusses mutations and hybridization in Cercocarpus and hybridization between Purshia tridentata and Cowania. Koehler and Smith (1981) describe hybrids of Cowania and Purshia glandulosa. Blauer and others (1975) discuss hybridization in Amelanchier, Cercocarpus, Purshia, and Rosa, and between Cowania and Purshia and between Cowania and Fallugia.

GEOGRAPHIC DISTRIBUTION

Figures 1 and 2 show the generalized ranges of 17 species of shrubs in the Rose family. As the specific ranges of these species become better known, outlying extensions are to be expected.

In the genus Prunus, bittercherry is confined to the Northwestern United States and portions of California, whereas the chokecherries are found in the mountains of the entire West except for the arid areas of southern California, southern Nevada, and western Arizona. No distinction is made in this paper between the ranges of the varieties P. v. melanocarpa and P. v. demissa. Prunus andersonii (Anderson peachbrush) and desert peachbrush have a much more limited range. The former occurs in the most arid portions of eastern California and western Nevada, while the latter occurs on similar sites in southeastern California, southern Nevada, northwestern Arizona, and the "Dixie" area of southwestern Utah (fig. 1).

Table 3.--Characteristics of vegetative reproduction and response to topkill of some Rosaceous shrubs

Antelope bitterbrush	Some ecotypes layer; some sprout after fire
Desert bitterbrush	Some ecotypes layer; sprouts well after fire
Woods rose	Spreads by root sprouts; sprouts well after fire
Saskatoon serviceberry	No vegetative reproduction; sprouts well after fire
Utah serviceberry	No vegetative reproduction; sprouts well after fire
Bittercherry	Spreads by root sprouts; sprouts after fire
Chokecherry	Spreads by root sprouts; sprouts after fire
Sandcherry	No vegetative reproduction; sprouts after fire
True mountain mahogany	No vegetative reproduction; some ecotypes sprout after fire
Curlleaf mountain mahogany	No vegetative reproduction; nonsprouting after fire
Cliffrose	No vegetative reproduction; nonsprouting after fire
Apache plume	Spreads by root sprouts; sprouts after fire
Spirea	Forms dense patches; sprouts well after fire
Oceanspray	Sprouts well after fire
Ninebark	Sprouts well after fire

Whereas antelope bitterbrush is widespread in the Western United States, desert bitterbrush is confined to arid sites over much the same area as desert peachbrush. The closely related cliffrose and apache plume are also found primarily in the Southwest, although the former does occur nearly to the northern Utah border. The *Purshia-Cowania-Fallugia* complex occurs with greatest diversity in the southeastern California to southern Nevada region (fig. 1).

Of the two most widespread species of serviceberry in the Western United States, Utah serviceberry tends to occupy the more xeric sites, and its range extends farther south than that of Saskatoon serviceberry (fig. 1).

Both curlleaf mountain mahogany and true mountain mahogany appear to have several ecotypes within the overall geographic range of each species. True mountain mahogany apparently does not occur in Idaho, but is found in the southwestern part of Oregon. On the other hand, curlleaf mountain mahogany does not occur as far eastward or as far southwestward as does true mountain mahogany (fig. 2).

The two species of mountain ash, Sitka mountain ash (*Sorbus sitchensis* Roemer) and Greene's mountain ash (*Sorbus scopulina* Greene), are primarily inhabitants of mesic sites in the montane coniferous forest, with only the latter occurring in the central and southern Rocky Mountains (fig. 2).

Of the several species of *Crataegus* found in the Western United States, the one most likely to be used for revegetation is Douglas hawthorn, of which there are four recognized varieties. No attempt has been made here to define the ranges of these varieties (fig. 2).

Among the potentially useful wild roses, Woods rose, Nootka rose (*Rosa nutkana* Presl.), and baldhip rose (*Rosa gymnocarpa* Nutt.) are all widespread. Prickly rose (*Rosa acicularis* Lindl.) is nearly as widespread but is not known in Utah and Nevada.

Bush cinquefoil occurs in all the Western States, including the mountains of Arizona and New Mexico. Of the 10 species of *Spiraea* in the Western United States, only the erect forms are likely to be much used for revegetation. Douglas spirea (*Spiraea douglasii* Hook.) occurs in the Pacific Northwest, including northern California, but is not found in Nevada, Utah, Wyoming, Colorado, or farther south. Subalpine spirea (*S. densiflora* Nutt.) and shiny-leaf spirea (*S. betulifolia* Pall.) are also predominantly Pacific Northwest species, although the former does extend into Nevada. The two most common species of *Holodiscus*, oceanspray, (*H. discolor* [Pursh] Maxim) and bush oceanspray (*H. dumosus* [Hook.] Heller) occupy somewhat different ranges: the former in the Pacific Northwest and California, and the latter in the drier areas of Utah, Nevada, Wyoming, Colorado, and southern Idaho.

In most cases mallow ninebark (*Physocarpus malvaceus* [Greene] Kuntze) has been the species of ninebark used for revegetation. Mallow ninebark occurs on drier sites than most other ninebark species, and is found in all 11 Western States except Arizona, New Mexico, and California (although entirely east of the Cascades in Washington and Oregon). A larger species, Pacific ninebark (*P. capitatus* [Pursh.] Kuntze), occurs west of the Cascades and throughout much of California, predominantly on moist sites. A disjunct population of Pacific ninebark has also been found in northern Idaho. Two other species, dwarf ninebark (*P. alternans* [Jones] T. J. Howell) and mountain ninebark (*P. monogynus* [Torr.] Coult.), also are potentially useful on specific sites: the former in Nevada, Utah, Colorado, Idaho, and California, often in juniper-pinyon habitats; and the latter in Nevada, Utah, Colorado, Wyoming, Arizona, and New Mexico, usually on relatively moist soils associated with aspen or coniferous forests.

Hitchcock and others (1961) list 17 species of the genus *Rubus* for the Pacific Northwest states, and other authors list other species in parts of the West. However, the most likely

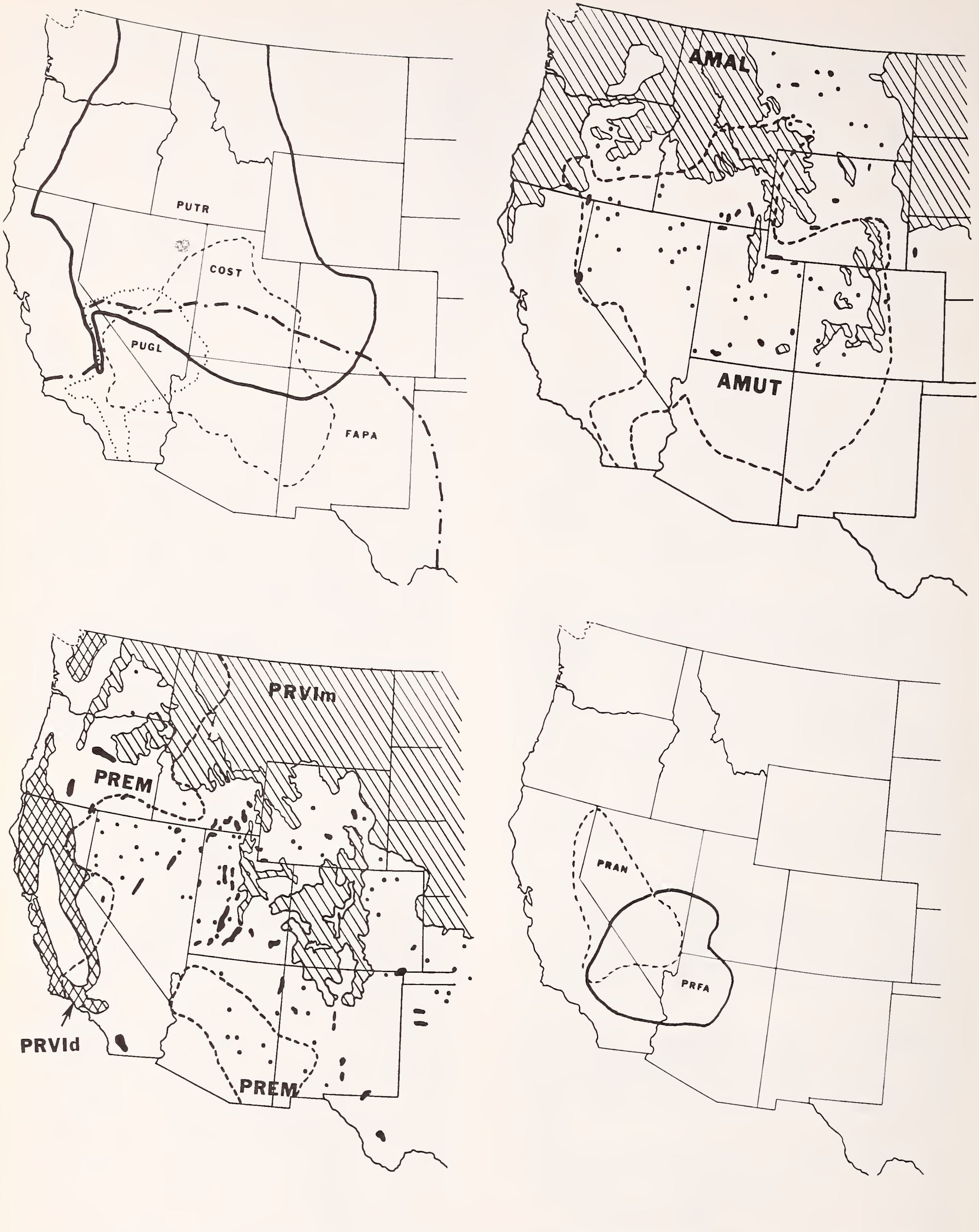

Figure 1.--Geographic range of antelope bitterbrush (PUTR), desert bitterbrush (PUGL), cliffrose (COST), apache plume (FAPA), Saskatoon serviceberry (AMAL), Utah serviceberry (AMUT), bittercherry (PREM), chokecherry (PRVI), Anderson peachbrush (PRAN), and desert peachbrush (PRFA) in the Western United States.

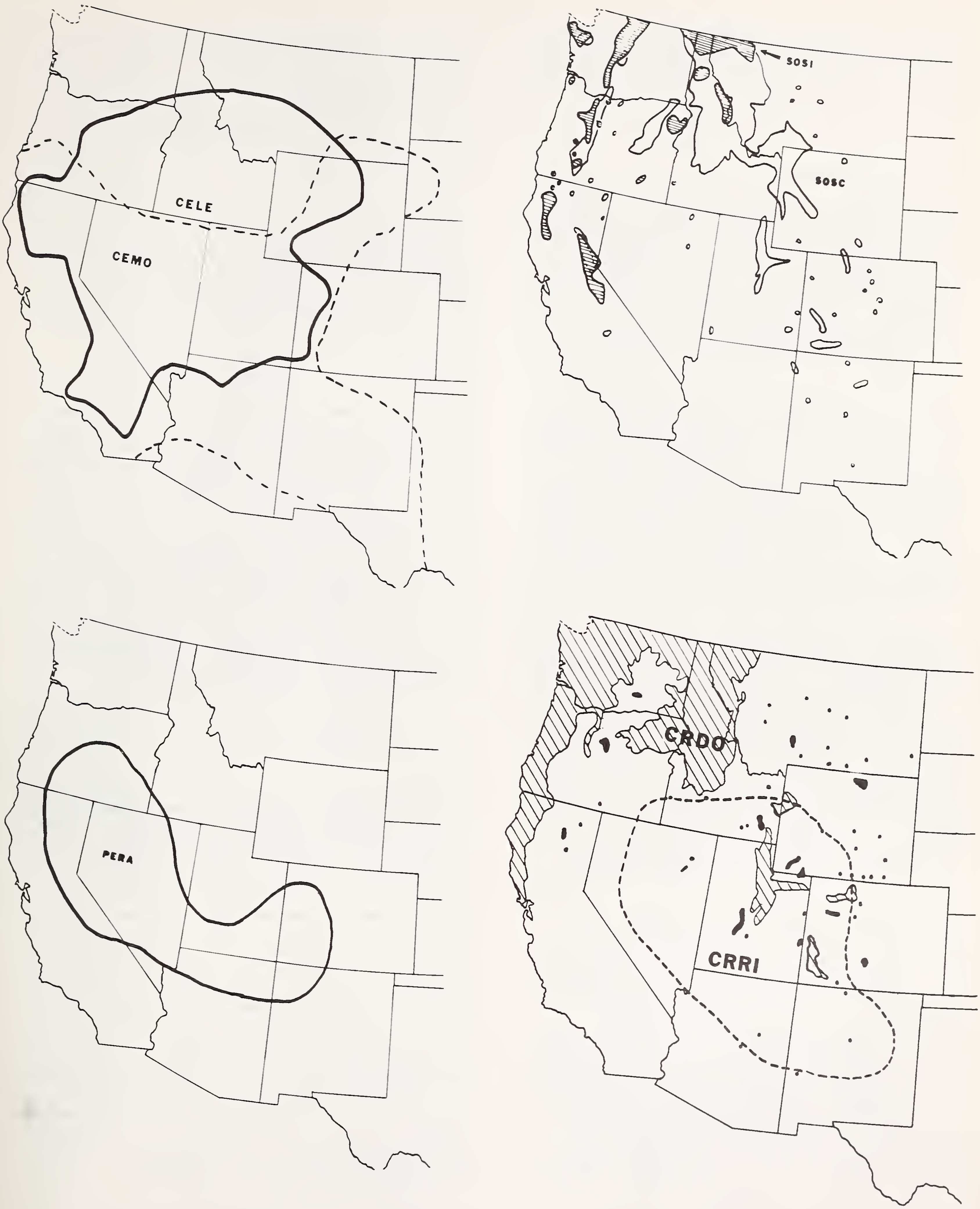

Figure 2.--Geographic range of curlleaf mountain mahogany (CELE), true mountain mahogany (CEMO), Greenes mountain ash (SOSC), Sitka mountain ash (SOSI), Douglas hawthorn (CRDO), river hawthorn (CRRI), and squawapple (PERA) in the Western United States.

species to be used in revegetation of disturbed areas is "blackcap" (R. leucodermis Dougl.), which occurs throughout the Western States. As do most species of Rubus, the blackcap occurs on moist soils, but can be established on sites such as roadcuts or along drainageways.

SPECIES SELECTION WITHIN ROSACEAE

Most rosaceous shrubs discussed here are adapted to areas receiving 10 inches (25 cm) or more of annual precipitation. Among this group, cliffrose and apache plume may be the most drought tolerant, closely followed by desert bitterbrush, desert peachbrush, Anderson peachbrush, littleleaf mountain mahogany (Cercocarpus intricatus S. Wats.), and some ecotypes of Utah serviceberry and antelope bitterbrush.

Selection of plant species for revegetation should involve careful search of the surrounding area to learn what native species occupy similar sites to the one scheduled for revegetation. The goal should be to use seed from adjacent, similar areas, or planting stock grown from such seed sources. Avoid untested and unproven plant materials from distant sources. Monsen (1975) states, "In highly disturbed areas, a general guideline has been to utilize the species from adjacent vegetative types that persist under more xeric conditions."

The juniper-pinyon and mountain brush vegetation types are especially well suited for the use of rosaceous shrubs. Plummer and others (1968) list 16 species as being adapted in these areas. In contrast, these authors list only bush cinquefoil and American plum from among the rose group as being adapted to wet meadow sites, and only desert peachbrush for use on saltbush and greasewood sites. Smith and others (1978) found Anderson peachbrush a good choice for establishment on highway roadcuts in the arid areas of Mono County, Calif. They also recommended cliffrose as suitable at locations receiving somewhat greater rainfall in Mono County.

Rosaceous shrub species are adapted to a wide range of soil types, but none are noted for tolerating saline soils in semi-arid or arid areas. However, Fedkenheuer and others (1980) reported that Saskatoon serviceberry, bush cinquefoil, and prickly rose were among the group of species with high survival rates on oil sand tailings in Alberta. The oil sand tailings were highly alkaline (pH 8.5±0.5). On acid mine spoils in Nevada, curlleaf mountain mahogany, black chokecherry, Saskatoon serviceberry, Pacific ninebark, antelope bitterbrush, Woods rose, and bittercherry all show considerable promise (Butterfield and Tueller 1980; Everett and others 1980).

Use of species native to a particular area is recommended, but use of non-native species may serve valuable purposes such as stability for soil, food for wildlife, or cover for wildlife. Cliffrose, apache plume, and specific ecotypes of desert bitterbrush have been successfully established on southern Idaho deer winter ranges (Monsen 1975). Dietz and others (1980) reported on the successful use of antelope bitterbrush (a non-native) in the Black Hills of South Dakota.

Tolerance to Fire

An important consideration when selecting plant species for revegetation is response to fire. Whereas most shrub species in the rose group exhibit vigorous sprouting after topkill by fire, three important species do not: curlleaf mountain mahogany, cliffrose, and antelope bitterbrush. Of the three, only antelope bitterbrush occasionally sprouts following complete topkill, with most surviving plants being the young, vigorous individuals. Driscoll (1963) believed that the capacity of antelope bitterbrush to sprout following fire was related to soil characteristics. Blaisdell and Mueggler (1956), working on the Snake River Plains of eastern Idaho, found that 50 percent of burned plants produced sprouts, but that 33 percent of those sprouting died within 16 months. The response of true mountain mahogany to fire is also variable, and possibly related to ecotypic variation. Most species of Rubus sprout vigorously following fire. Greene's mountain ash, on the other hand, is eliminated by burning (Lyon 1966). Table 3 summarizes the response to fire of rosaceous shrubs most often used for revegetation in the Intermountain West.

Response to Animal Use

In general, the rosaceous shrubs are quite tolerant of animal use. Species of serviceberry and curlleaf mountain mahogany are perhaps more tolerant of heavy browsing by game animals than is antelope bitterbrush (Shepherd 1971). Garrison (1953) suggested that, for sustained shrub production, safe levels of use for antelope bitterbrush, curlleaf mountain mahogany, and oceanspray should be between 50 and 60 percent. Shepherd (1971) suggested that the summer and fall use of 20 to 40 percent of current annual growth of antelope bitterbrush would promote plant health and vigor, that 50 percent use might be acceptable, but that a sustained use of 80 percent or more would eventually damage or kill many plants. He believed that optimum use levels for winter could be somewhat higher. Shepherd stated that true mountain mahogany should be extremely productive and resistant to browsing intensities of 60 to 80 percent, and 70 percent use would be near optimum. He recommended 60 percent use of the current year's growth of Saskatoon serviceberry stems.

At times when other food is scarce, or during population irruptions, rodents may severely damage shrubs. In Oregon, Spencer (1958)

recorded serious barking and girdling of antelope bitterbrush, black chokecherry, mountain mahogany, rose, and other shrubs by mice (Microtus, Lagurus, and Clethrionomys). Also in Oregon, Mitchell (1951) noted an irruption of Microtus montanus that, by girdling, killed 90 percent of the bitterbrush on large areas. Brown and Martinsen (1959) recorded severe damage to planted Bessey cherry (Prunus besseyi Bailey) and American plum. Only those shrub species incapable of resprouting from the rootcrown are likely to be completely killed by rodent girdling. On mixed grass-shrub areas, rodent damage can be decreased by allowing the protective grass cover needed by the rodents to be grazed sufficiently by livestock.

Effects of Insects and Disease

Sudden outbreaks of damaging insects, or disease epidemics, may occur in any vegetation type, leaving the range manager almost helpless to stop severe damage to particular plant species or even to virtually all vegetation in the area affected. Grasshoppers are capable of destroying plantations of antelope bitterbrush seedlings, whether they be from direct seeding or transplanted nursery stock. Cutworms and wireworms have destroyed newly emerged antelope bitterbrush seedlings (Hubbard 1956). Tent caterpillars have caused widespread damage to antelope bitterbrush through defoliation (Hubbard and others 1959), and commonly infest stands of chokecherry, bittercherry, cliffrose, and curlleaf mountain mahogany. Van Epps and Furniss (1981) reported severe damage to a 13-year-old antelope bitterbrush plantation by the walnut spanworm (Phigalia plumogeraria Hulst.).

The mountain mahoganies are relatively free of attack by insects and disease. However, the looper (Anacamptodes clivinavia profanata B. and McD.), a leaf defoliator, destroyed 46 percent of a 5,900-acre (2,400-ha) stand of curlleaf mountain mahogany over 3 years in southwestern Idaho (Furniss and Barr 1967). Such drastic effects tend to be rare but do serve to illustrate what can happen after an extreme population increase of an insect.

Species of Prunus and Amelanchier seem to be bothered more by diseases than other rosaceous shrubs. Chokecherries carry western X-disease, which affects fruit trees, and are often infected with Black Knot canker (Dibotryon morbosum [Schw.] Th. & Syd.). The chokecherries are intermediate in sensitivity to sulfur dioxide and fluorides, two common components of air pollution (Anderson 1966; Carlson and Dewey 1971; Shaw 1952). Both Saskatoon serviceberry and Utah serviceberry are commonly infected with rusts caused by Gymnosporangium spp. (Furniss and Krebill 1972). These rusts usually occur on the fruit and leaves, and occasionally on the stems. The degree of damage caused by the rusts is not known, but some plant pathologists believe that a heavy level of infection is damaging. Serviceberry plants are highly sensitive to sulfur dioxide and fluorides in the atmosphere.

Response to Herbicides

Herbicides can be used on vegetation that includes rosaceous shrubs if care is taken to consult the literature beforehand so that treatment can be designed to minimize the damage to the desirable species. Hyder and Sneva (1962) concluded that the proper timing for spraying mixed stands of big sagebrush and antelope bitterbrush on dry sites with 2,4-D or 2,4,5-T was when new leaves appeared on those plants, and that spraying could then be done until bitterbrush was in flower. Trout (1968) recommended no spraying with 2,4-D on ranges with a significant number of young or seedling antelope bitterbrush. Trout found that where mature antelope bitterbrush was sprayed with 2,4-D, plants regained full vigor in about 4 years. Pechanec and others (1965) noted that Saskatoon serviceberry and black chokecherry were among the most susceptible shrubs to damage from 2,4-D--damaged even more than bitterbrush. Mueggler (1966) found that Saskatoon serviceberry, bittercherry, and oceanspray were all moderately sensitive to sprays of 2,4-D, 2,4,5-T, and combinations of the two chemicals. However, he noted that the amount of basal sprouting from serviceberry did not equal the amount of crown kill. Mueggler also reported that oceanspray sprouted rather profusely and was not materially harmed by aerial spraying. Trout (1968) also reported basal sprouting of Saskatoon serviceberry the spring following spraying with 2,4-D. Gratkowski (1978) reported that a temporary reduction of the crown size of Saskatoon serviceberry was the only result of spraying with either of several herbicides, including 2,4-D and 2,4,5-T. However, he also noted that serviceberry sprayed with 2,4-D still had not recovered its original vigor 19 years after being sprayed. Gratkowski's tests of several combinations of herbicides on thimbleberry (Rubus parviflorus Nutt.) indicated that this species is easily damaged or killed by spraying. Fisser (1981) found that the use of Tordon spray treatment in August, to control juniper (Juniperus spp.), at a rate of 2 lbs/acre (3.63 kg/ha) A.I., was lethal to curlleaf mountain mahogany.

Researchers of the Potlach Corporation in northern Idaho have studied the effects of the herbicides Garlon 3A, Garlon 4, Velpar L, 2,4-D, and Roundup on woody species in that region, including Saskatoon serviceberry, thimbleberry, mallow ninebark, oceanspray, bittercherry, bald hip rose, shiny-leaf spirea, and trailing blackberry (Rubus sp.). While too detailed to discuss here, the reader is referred to Miller (1981), and Miller and Pope (1982a and 1982b).

Another excellent guide to the susceptibility of many plant species to foliage application of

phenoxy herbicides was compiled by Parker (1982).

Effects of Shade and Competing Vegetation

In general, rosaceous shrubs are not very tolerant of either shade or competition for soil moisture. The most shade tolerant also tend to grow on moist sites: the spireas, mallow ninebark, species of Rubus, and Saskatoon serviceberry. Bush cinquefoil is intolerant of shade but is a good competitor with herbaceous plants. Few bitterbrush seedlings survive in cheatgrass (Bromus tectorum L.), according to Holmgren (1956), and competition with broad-leaved annuals reduces seedling vigor. Hubbard's findings (1957), which agreed with Holmgren's, also concluded that desert wheatgrass (Agropyron desertorum [Fisch.] Schult.) was as severe a competitor as native vegetation. Hubbard and Sanderson (1961) concluded that dense grass competition significantly reduced the yield and vigor of mature antelope bitterbrush. Monsen (1975) felt that bitterbrush seedlings of low-growing ecotypes were more competitive with herbaceous vegetation than were seedlings of more upright forms.

Forage Value

Merrill (1972) said, "Nearly all shrub....species are consumed at some time by livestock or big game." Many shrubs of the rose family are preferred browse of game animals and livestock. However, the many species, and their ecotypes, do exhibit considerable variability in their relative attraction to foraging animals. For example, true mountain mahogany is considered a better browse for livestock than is curlleaf mountain mahogany, and antelope bitterbrush is usually more palatable to deer than is desert bitterbrush. Although squawapple has not been considered palatable forage, Hayes and Garrison (1960) did consider this species as fair browse for both deer and livestock in Oregon. And although bush cinquefoil is generally avoided by big game in Alberta, Canada, it has been reported palatable to deer in Montana and Arizona.

Several rosaceous shrubs are potentially toxic to grazing animals. Brotherson and Osayande (1980) noted that because of a high concentration of copper in true mountain mahogany tissue, copper toxicity is a distinct possibility in ruminants that forage on it. However, under winter conditions, animals would probably be poisoned only if true mountain mahogany were their sole diet.

Majak and others (1980) found that Saskatoon serviceberry contained high levels of the cyanogenic glycoside, prunasin. They reported that mature mule deer died after consuming Saskatoon serviceberry twigs at the rate of 2.54 lb (1 kg) per day for a week. Their preliminary research also indicated that the prunasin concentration in new growth of black chokecherry is considerably higher than in Saskatoon serviceberry. Despite the demonstrated high levels of toxic compounds in many plant species, wild animals apparently include enough of a variety of plants in their diet to avoid lethal amounts of toxic material. Where domestic animals are confined to areas having a high density of toxic plants, and an insufficient quantity of other forage species, poisoning can occur.

The nutritive quality of rosaceous shrubs is high. Dietz (1972) reported that the stems of black chokecherry and Saskatoon serviceberry showed an increase in protein from fall to winter. He also noted that the comparatively high protein level in chokecherry winter stems may help explain its high use by deer during fall and winter. In his early work with captive mule deer in Utah, Smith (1950; 1953) found that curlleaf mountain mahogany, antelope bitterbrush, and cliffrose were the top three plant species selected by mule deer from among 16 plants available to them during the winter. True mountain mahogany, black chokecherry, and Saskatoon serviceberry ranked fifth, seventh, and eighth, respectively. During summer, the captive deer selected Saskatoon serviceberry (seventh), curlleaf mahogany (ninth), and black chokecherry (tenth) from among 32 species made available to them.

In subsequent work with penned deer, Smith and Hubbard (1954) continued to find that curlleaf mountain mahogany, cliffrose, and bitterbrush were the most preferred species for winter forage, with chokecherry and serviceberry also readily taken. Because of their retention of high crude protein and energy levels, evergreen species are of particular nutritive value to animals during winter. In this respect, curlleaf mountain mahogany, cliffrose, desert bitterbrush, and apache plume are all valuable winter browse plants. Wild roses are excellent summer forage plants, but crude protein content decreases considerably once the leaves are shed. Rose hips, however, are high in digestibility and moderately high in winter crude protein. When hips are abundant they add greatly to the value of rose as a forage. Shrubs of the genera Rubus, Sorbus, and Holodiscus occur mostly on the summer ranges of big game and livestock and are less often used as forage by these animals. Brown and Martinsen (1959) found that the palatability of Douglas hawthorn was good and that deer use had been moderate to heavy on Washington winter range. The spireas and ninebarks have poor reputations as forage plants.

METHODS OF ESTABLISHMENT

Direct Seeding

The greatest deterrent to the direct seeding of rosaceous shrubs is depredation on seed by

rodents. The gathering and caching of bitterbrush seed by rodents has been documented by numerous authors (Hormay 1943; Nord 1965; Sanderson 1962). Holmgren and Basile (1959) discussed the need for and use of endrin-arasan treated bitterbrush seed in southern Idaho. Everett and others (1978) noted that mice prefer seed of curlleaf mountain mahogany, antelope bitterbrush, and Saskatoon serviceberry. Since the use of endrin has been prohibited or looked upon with disfavor, effective substitute compounds for rodent-repelling seed treatments have not been found. Alpha-naphthylthiourea appears to hold some promise (Passof and others 1974; Everett and others 1978).

Direct seeding can be successful if the following conditions are met: (1) good quality seed is sown in the autumn, (2) seed is sown at the proper depth, (3) rodent populations are low or are controlled, (4) site preparation has sufficiently controlled herbaceous plant competition with the newly emerged shrub seedlings. Nearly all rosaceous shrub seed germinates best when well covered with soil. Broadcast seeding of shrub species--especially if seed is sown in a mixture with grasses and forbs--seldom results in as high a stand density as drilling or seed spotting. The author has seen several very successful direct seeding projects wherein the seed dribbler was used while juniper and pinyon trees were cleared with a caterpillar tractor.

The scarcity or expense of seed is another factor to consider when planning the use of rosaceous shrubs. Seed of squawapple, apache plume, bush cinquefoil, blackcap raspberry, thimbleberry, ninebark, spirea, and oceanspray are seldom available commercially; when they are, it is only at great cost. Even particular ecotypes of the more commonly available antelope bitterbrush, mountain mahoganies, cliffrose, and the serviceberries are difficult to obtain in quantity. These considerations usually make transplanting attractive, especially if great stand density is not desired, nursery stock is available, and the area scheduled for revegetation is not large.

Transplanting

The advantages of using nursery-grown planting stock, rather than attempting direct seeding for the establishment of shrubs, are: (1) transplants are less susceptible to damage by insects, damping off, animal trampling and grazing, erosion, and high temperatures than seedlings; (2) transplants usually are larger after 1 or 2 years than seedlings; (3) plants can be placed at desired locations and density closely controlled; and (4) transplants are able to compete better with adjacent vegetation than are seedlings. Disadvantages are the greater costs of planting material and field planting.

Nearly all rosaceous shrubs can be established from bare-root nursery stock if planting is done properly in early spring with hardened, dormant plants and if herbaceous competition is controlled. The mountain mahoganies are perhaps more reliably established from container-grown transplants. In arid areas, small basins about 1 ft (30 cm) in diameter greatly aid transplant survival by providing a catchment for subsequent rainfall. If feasible, the addition of 1 or 2 qt (1 or 2 l) of water to each planting spot at the time of planting increases the chances for survival. Everett (1980) found Woods rose and antelope bitterbrush among the best species for revegetating south-facing roadcuts in Nevada. Smith and others (1978) had good success with container-grown stock of Anderson peachbrush on harsh roadcuts in Mono County, Calif. Container-grown plants of curlleaf mountain mahogany exhibited 91 percent survival 4 years after being planted on acid mine spoil material in Nevada (Butterfield and Tueller 1980).

Most rosaceous shrubs are somewhat slower growing than many chenopods and composites. True and curlleaf mountain mahoganies, serviceberry, squawapple, and to a lesser extent, chokecherry and bittercherry benefit from protection from foraging animals for at least 3 years following establishment.

Several of the rosaceous shrubs may be propagated from cuttings. True mountain mahogany, river hawthorn, Illinois ninebark (Physocarpus intermedius [Rydb.] Schneid.), bush cinquefoil, Arkansas rose (Rosa arkansana Porter), and spirea (four introduced species) were all successfully rooted from cuttings by Howard and others (1979). Everett and others (1978) were unable to obtain rooted cuttings of Saskatoon serviceberry, Utah serviceberry, or curlleaf mountain mahogany, but an average of 43 percent of the cuttings from three accessions of Woods rose were rooted. Cliffrose, western chokecherry (Prunus virginiana L. var. demissa Nutt.), and antelope bitterbrush all exhibited 5 percent or less rooting capacity. Rooted cuttings are usually transferred to containers or into nursery beds for a sufficient time for adequate root system development before being planted at a field location.

Tree and shrub establishment, especially on raw soil materials that are low in soil nutrients and microorganisms, may be enhanced by mycorrhizal symbionts. Most and perhaps all rosaceous shrubs are associated with endomycorrhizae. Williams and Aldon (1976) identified endomycorrhizae on roots of mountain serviceberry (Amelanchier oreophila A. Nels.), Utah serviceberry, true mountain mahogany, apache plume, bush oceanspray, and antelope bitterbrush. Barnhill (1981) found that roots of Malus seiboldi (Reg.) Rehd., Prunus besseyi Bailey, and Prunus munsoniana Bailey were infected with endomycorrhizae. Researchers are currently studying the efficacy of mycorrhizae to improve plant establishment and growth. In the near future a likely accepted practice will be the inoculation of nursery-grown planting stock with host-specific species of mycorrhizae.

Herbicide use is an additional site preparation method that could bring about shrub establishment where herbaceous plant competition is severe. Glyphosphate, dalapon, or atrazine can all be used on selected spots or strips prior to the shrub planting. Herbaceous vegetation killed by the herbicide would serve as a mulch and decrease the loss of soil moisture to evaporation.

Additional research is needed to select and develop specific ecotypes of rosaceous shrubs for use on disturbed sites in the Western United States. Current research at the Forest Service's Shrub Improvement Laboratory in Provo, Utah, is designed to accomplish this goal for the bitterbrush-cliffrose-apache plume complex.

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IMPORTANT SHRUBS FOR WILDLAND PLANTINGS, COMPOSITAE (ASTERACEAE)

E. Durant McArthur

ABSTRACT: The shrublands of the Intermountain West include a significant portion of composite shrubs. Sagebrush (Artemisia) is a continental scale dominant; rabbitbrush (Chrysothamnus), goldenbush (Haplopappus), matchbrush (Xanthocephalum), and horsebrush (Tetradymia) are also important. These shrubs provide soil stabilization, feed, cover, and other present and potential uses. Their value for wildlife habitat is substantial. Of the wildlife species in sagebrush vegetation types, 87 are identified. Positive values of composite shrubs have generally been underestimated.

INTRODUCTION

The Intermountain West is, in large measure, shrubland (Küchler 1964; Bailey 1976). For example, about 46 percent of Wyoming's land area, under natural conditions, is dominated by shrubby vegetation (McArthur 1981). Several families contribute species to the West's shrubby flora. The most important, in terms of number of species and area of land occupied in the Intermountain Area, are the Compositae, Chenopodiaceae, and Rosaceae (Blauer and others 1975; 1976; McArthur and others 1979). Two families (Compositae and Chenopodiaceae) dominate large tracts of land, often in closed or semiclosed stands. The rose family includes 19 genera of western shrubs, but they are usually found in mixed vegetative communities or in scattered stands. If the criterion of providing dominant plants to Küchler's (1964) vegetative types is used (McArthur[1]), then 12 other families are also important contributors to the western (west of 100° W longitude) shrubby flora.

E. Durant McArthur is Principal Research Geneticist, Shrub Sciences Laboratory, Intermountain Forest and Range Experiment Station, USDA Forest Service, Ogden, Utah. This review was facilitated by cooperative research between the Intermountain Forest and Range Experiment Station and the Utah Division of Wildlife Resources, Pittman Robertson Project W-82-R.

[1]McArthur, E. D. Natural diversity of western range shrubs. In: Cooley, J. L.; Cooley, J. H., eds. Natural diversity in forest ecosystems; 1982 November-December; Athens, GA. Athens, GA: Institute of Ecology, University of Georgia. In press.

Two major shrub-dominated vegetative types contribute to the prominence of the chenopod and composite families. These are the salt desert and sagebrush types. Each type can be subdivided. Stutz (this proceedings), Blauer and others (1976), and McArthur and others (1978b) treat the salt desert species, mainly Atriplex. Sagebrush (Artemisia, subgenus Tridentatae) dominated lands were separated into the sagebrush steppe, Great Basin sagebrush, and wheatgrass-needlegrass shrubsteppe types by Küchler (1964). Finer divisions into habitat types listing two to four major species have been and are being made (Hironaka 1979; Winward 1980; 1983; Blaisdell and others 1982). One should bear in mind, however, that mosaics of the various salt desert and sagebrush types often occur. Other composite family shrubs, rabbitbrush (Chrysothamnus), goldenbush (Haplopappus), matchbrush or snakeweed (Xanthocephalum), and horsebrush (Tetradymia) also occur in considerable numbers in the salt desert and sagebrush vegetative types. Atriplex and especially Artemisia species are found in other vegetative types besides those they dominate.

Although in this paper I do not treat each of the composite species in detail, the major species are mentioned. I also make comments about uses and values and give literature references to more thorough treatments of the species. For more information, I recommend two major recent reviews of sagebrush areas (Tisdale and Hironaka 1981; Blaisdell and others 1982) and a symposium proceedings (Utah State University 1979).

IMPORTANT COMPOSITE RANGE SHRUBS

There are 18 genera of composite shrubs in the United States west of 100° W longitude (McArthur, see footnote 1). However, the most important shrubs, in terms of number of taxa and area of land covered in the Intermountain area, belong to the genera Artemisia, Chrysothamnus, Haplopappus, Tetradymia, and Xanthocephalum (table 1). Artemisia is by far the most important.

These shrubs are all common in the sagebrush ecosystems or vegetative types. And like the Artemisias, each genus has its species distributed along moisture and elevation gradients (Barker 1981; Shultz 1983). Soils are also important. Soil types interact with elevation and especially moisture gradients in influencing plant distribution. The sagebrush vegetative types are climax, and from the

Table 1.--Important composite range shrubs

Important[1] species	No. of subspecies	Important subspecies
Artemisia, tribe Anthemideae		
400 species, mostly Northern Hemisphere, herbs and shrubs (Keck 1946; McArthur 1979; 1982; McArthur and others 1979; 1981).		
A. arbuscula	2	*arbuscula*, *thermopola*
A. argillosa	--	
A. bigelovii	--	
A. cana	3	*bolanderi*, *cana* *viscidula*
A. dracunculus	3-5	
A. filifolia	--	
A. frigida	--	
A. longifolia	--	
A. longiloba	--	
A. ludoviciana	7	
A. nova	--	
A. pedafifida	--	
A. pygmaea	--	
A. rigida	--	
A. rothrockii	--	
A. spinescens	--	
A. tridentata	4	*spiciformis*[2], *tridentata*, *vaseyana*, *wyomingensis*,
A. tripartita	2	*rupicola*, *tripartita*
Chrysothamnus, tribe Astereae		
14 species, endemic to western North America, shrubs only (Anderson 1970; McArthur and others 1979; McArthur, see text footnote 1).		
C. albidus	--	
C. depressus	--	
C. greenei	--	
C. linifolius	--	
C. nauseosus	21	*albicaulis*, *consimilis* *graveolens*, *hololeucus*, *junceus*, *leiospermus*, *salicifolius*, *turbinatus*
C. parryi	12	*attenuatus*, *howardi*, *nevadensis*, *parryi*
C. vaseyi	--	
C. viscidiflorus	5	*lanceolatus*, *puberulus*, *viscidiflorus*
Haplopappus, tribe Astereae		
150 species, endemic to the Americas, more herbs than shrubs (Hall 1928; USDA 1937; McArthur, see text footnote 1).		
H. bloomeri	--	
H. greenei	--	
H. macronema	--	
H. suffruticosus	--	

Table 1. (con.)

Important species	No. of subspecies	Important subspecies
Tetradymia, tribe Senecioneae		
10 species, endemic to western North America, all shrubs (Strother 1974; McArthur and others 1979).		
T. axillaris	--	
T. canescens	--	
T. glabrata	--	
T. nuttallii	--	
T. spinescens	--	
T. stenolepis	--	
T. tetrameres	--	
Xanthocephalum, tribe Astereae		
11 species, endemic to the Americas, mostly in North America, shrubs and herbs (McArthur and others 1979; McArthur, see text footnote 1).		
X. microcephala	--	
X. sarothrae	--	

[1] Species common in parts of the Intermountain area or deemed useful for revegetation work.
[2] Not formally described at the subspecific rank although it has been described at the species and form levels.

human perspective, have been in place for a long time. In terms of geological time, they are young (Axelrod 1950; McArthur and others 1981). The most stable parts of the sagebrush vegetative types are the shrubs. In many locations formerly associated forbs and grasses have been severely reduced in number or eliminated by the introduction of grazing animals. In those areas the shrubs have often become more numerous, or introduced weeds (cheatgrass, medusahead, and others) have become common.

USES

Soil Stabilization

Many of the composite shrubs of the Intermountain region grow in dry areas and thus keep soil in place. In addition to providing natural soil binding, several species of *Artemisia* and *Chrysothamnus* are suitable for stabilizing disturbed soils by transplanting or seeding (McArthur and others 1974; Plummer 1977). Some special cases can be made for planting species to stabilize disturbed areas based on their natural distribution and adaptation. When doing so, it is important to try to match precipitation, soil, and elevation with the plant's original source site and to bear in mind the importance of special care in initial establishment. The suggested plantings:

Poorly drained, heavy soils--

- A. argillosa
- A. cana
- A. frigida
- A. longifolia
- A. longiloba
- C. nauseosus, ssp. consimilis

Intermittent drainage channels--

- A. ludoviciana
- C. parryi ssp. attenuatus
- C. linifolius

Sandy areas--

- A. filifolia
- C. nauseosus ssp. turbinatus
- C. nauseosus ssp. junceus

Well drained, dry rocky areas--

- A. arbuscula
- A. bigelovii
- A. nova
- A. rigida
- A. tridentata ssp. wyomingensis
- C. nauseosus ssp. albicaulis
- C. viscidiflorus

Saline, moist areas--

- C. albidus

Wildlife Habitat

The sagebrush vegetative types, including the other composite genera, provide significant areas of wildlife habitat. Table 2 shows 87 wildlife species that use sagebrush for habitat in eight Intermountain States. Species with particularly close association with sagebrush areas include mule deer, pronghorn antelope, badger, coyote, bobcat, striped skunk, least chipmunk, northern grasshopper mouse, western harvest mouse, deer mouse, Ord's kangaroo rat, black-tailed jackrabbit, desert cottontail, sage grouse, American kestrel, golden eagle, turkey vulture, and red-tailed hawk. Each of these received at least 75 points (maximum possible, 100) for their association with sagebrush vegetative types (table 2). The sagebrush types had among the highest wildlife values of any of the general vegetative types in the broad comparisons made by the Institute for Land Rehabilitation staff (1978). The states in the center of sagebrush distribution (Nevada, Idaho, Utah, Colorado, Wyoming) had higher wildlife habitat point totals for sagebrush-associated wildlife than states on the periphery (Arizona, New Mexico, Montana) (table 2). More detailed treatments of wildlife habitat are in Wallmo (1975), McArthur and others (1978b), and Blaisdell and others (1982).

Feed Value

Range shrubs in general are valuable feed sources for wildlife and livestock, especially evergreen shrubs in the winter (Cook 1972; Dietz 1972; Welch 1981). Big sagebrush (Artemisia tridentata) has excellent values for crude protein, total digestible nutrients, calcium, phosphorus, and carotene (Welch and McArthur 1979; Welch 1981). The practical feed value of sagebrush species is reduced because the plants are not as palatable to wildlife and especially livestock as are other shrubs (Smith and Hubbard 1954; Welch and McArthur, unpublished). A notable exception to the reduced palatability of sagebrush is the dietary habit of the pygmy cottontail, whose meals are 99 percent sagebrush in the winter, about 66 percent on an annual basis, and no less than 43 percent during any period (Green and Flinders 1980). Despite the low preference for sagebrush and rabbitbrush, large amounts of various kinds of the two shrubs are consumed by wildlife (Leach 1956; Kufeld and others 1973; McArthur and others 1978a) and livestock (USDA 1937; Cook and others 1954; Holmgren and Hutchings 1972; Sheehy and Winward 1981). There are dramatic differences in preference by browsing animals among the composite plant taxa, even among subspecies (Hanks and others 1973; 1975; Scholl and others 1977; McArthur and others 1978a; Sheehy and Winward 1981; Welch and others 1981). Nagy and others (1964) proposed that essential oils of Artemisia made that plant an undesirable forage because the oils would interfere with ruminant digestion. However, the concentration of oils in animal rumens are not high enough to be inhibitory (reviewed by Welch and others 1982). Effort in our laboratory aims to improve nutrient quality of big sagebrush by selecting for high protein, growth form, and palatability, through a breeding program (Welch and McArthur 1979; McArthur 1981).

A mix of composite and other shrubs with grasses and forbs is generally better for total productivity on a site. In that situation, generally more wild animals and larger numbers of livestock can be productively accommodated (Plummer and others 1968; Reynolds 1980; Otsyina and others 1982; Rumbaugh and others 1982).

The large distributional extent, high population numbers, and well adapted nature of the composite shrubs behooves managers to look at composite shrubs in a more positive manner than they often do. Zimmerman (1980), for example, noted that cattle can do well on shrub lands even in the midst of horsebrush (Tetradymia)!

Other Values

Other values among composite shrubs are serving as vegetative snow-fences and providing potentially rare chemicals. Laycock and Shoop (1982) reported that basin big sagebrush (A. tridentata ssp. tridentata), spreading rabbitbrush (C. linifolius), and white rubber rabbitbrush (C. nauseosus ssp. albicaulis) make excellent living snow-fences in northeastern Colorado. As long ago as World War I, rubber rabbitbrush was thought to have potential

Table 2.--Occurrence of wildlife species by State in the various sagebrush vegetation types[1]

Animal species	AZ	CO	ID	MT	NV	NM	UT	WY	Species points
	State								
UNGULATES									
Elk	-	X	L	X	-	X	L	-	50
Mule deer	X	X	X	X	X	X	X	X	100
Pronghorn antelope	L	X	X	X	X	X	X	X	94
CARNIVORES									
Badger	X	X	X	X	X	X	X	X	100
Coyote	X	X	X	X	X	X	X	X	100
Bobcat	X	L	L	X	L	X	X	X	81
Striped skunk	-	X	X	X	L	X	X	X	81
Spotted skunk	-	X	-	L	-	-	-	-	19
Long-tailed weasel	-	X	L	-	X	-	X	X	56
Short-tailed weasel	-	-	L	L	-	-	-	-	12
Kit fox	-	L	-	-	L	-	L	-	19
Red fox	-	-	L	-	-	-	-	X	19
Gray fox	X	-	-	-	-	-	-	-	12
Ermine	-	X	-	-	-	-	-	-	12
Mountain lion	-	X	-	-	-	-	-	-	12
Ringtail cat	X	-	-	-	-	-	-	-	12
SMALL MAMMALS									
Least chipmunk	X	X	X	X	X	X	X	X	100
Colorado chipmunk	X	-	-	-	-	-	-	-	12
Northern grasshopper mouse	X	X	X	X	X	X	X	X	100
Southern grasshopper mouse	-	-	-	-	-	X	-	-	12
Western harvest mouse	X	X	X	X	X	X	X	X	100
Deer mouse	X	X	X	X	X	X	-	X	88
Brush mouse	-	L	-	-	-	X	-	-	19
Great Basin pocket mouse	-	-	X	L	X	-	X	L	50
Little pocket mouse	-	-	X	-	X	-	-	-	25
Silky pocket mouse	X	-	-	-	-	L	-	-	19
Long-tailed pocket mouse	L	-	-	-	L	-	-	-	12
Olive-backed pocket mouse	-	-	-	-	-	-	-	X	12
Hispid pocket mouse	-	-	-	-	-	-	-	X	12
Dark kangaroo mouse	-	-	-	-	L	-	-	-	6
Ord's kangaroo rat	X	X	X	X	X	X	X	X	100
Chisel-toothed kangaroo rat	L	-	-	-	X	-	-	-	19
Panamint kangaroo rat	-	-	-	-	X	-	-	-	12
Desert woodrat	L	X	L	-	X	-	-	-	38
Bushy-tailed woodrat	-	X	L	-	L	-	-	-	25
Stephen's woodrat	L	-	-	-	-	-	-	-	6
Black-tailed jackrabbit	X	X	X	L	X	X	X	X	94
White-tailed jackrabbit	-	-	L	X	L	X	X	-	50
Antelope jackrabbit	L	-	-	-	-	-	-	-	6
Desert cottontail	X	X	X	X	-	X	X	X	88
Nuttall's cottontail	-	X	-	X	X	L	X	-	56
Pygmy cottontail	-	-	X	L	X	-	X	-	44
Northern pocket gopher	-	X	X	X	L	-	X	X	69
Valley pocket gopher	X	-	-	-	X	L	X	-	44
Townsend pocket gopher	-	-	X	-	-	-	-	-	12
Sagebrush vole	-	X	L	X	X	-	X	X	69
Long-tailed vole	-	X	L	X	L	-	X	L	56
Montane vole	-	-	L	-	L	-	X	X	38
Prairie vole	-	-	-	L	-	-	-	-	6
Richardson ground squirrel	-	X	X	L	L	-	-	X	50
Antelope ground squirrel	-	-	X	-	X	L	L	-	38
Harris antelope ground squirrel	X	-	-	-	-	-	-	-	12
Thirteen-lined ground squirrel	-	X	-	L	-	L	-	X	38
Golden-mantled ground squirrel	-	-	-	-	L	-	L	X	25
Piute ground squirrel	-	-	-	-	X	-	X	-	25
Belding ground squirrel	-	-	X	-	L	-	-	-	19
Uinta ground squirrel	-	-	-	-	-	-	-	X	12
Spotted ground squirrel	-	-	-	-	-	-	-	L	6
Rock squirrel	-	-	-	-	L	-	-	-	6

Table 2.--(con.)

Animal species	AZ	CO	ID	MT	NV	NM	UT	WY	Species points
					State				
Gunnison prairie dog	-	X	-	-	-	L	X	-	31
White-tailed prairie dog	-	X	-	-	-	-	-	X	25
Black-tailed prairie dog	-	-	-	-	-	-	-	X	12
Utah prairie dog	-	-	-	-	-	-	L	-	6
Yellow-bellied marmot	-	X	-	-	X	-	-	-	25
Porcupine	-	L	-	L	L	-	-	-	19
Pika	-	-	-	-	L	-	-	-	6
GAME BIRDS									
Sage grouse	-	X	L	X	L	X	X	X	75
Sharp-tailed grouse	-	X	L	-	X	-	L	X	50
Blue grouse	-	-	L	L	L	-	X	L	38
Mourning dove	X	-	X	X	X	-	X	-	62
Chukkar	-	X	L	-	L	X	L	-	44
Gambel quail	X	-	L	-	-	-	-	-	19
RAPTORS									
American kestrel	X	X	X	X	X	X	X	X	100
Golden eagle	X	X	X	-	X	X	X	X	88
Turkey vulture	X	X	X	-	X	-	X	X	75
Red-tailed hawk	X	X	X	-	X	-	X	X	75
Swainson's hawk	X	X	X	-	X	-	X	X	62
Marsh hawk	-	X	L	-	X	-	X	X	56
Ferruginous hawk	X	-	L	-	-	X	X	-	44
Cooper's hawk	-	-	-	-	X	-	L	-	19
Sharp-skinned hawk	X	L	-	-	-	-	-	-	19
Prairie falcon	-	-	L	-	X	X	L	X	50
Burrowing owl	-	-	X	-	X	-	-	X	38
Great horned owl	-	-	L	-	L	-	X	X	38
Short-eared owl	-	-	X	-	-	-	-	X	25
Long-eared owl	-	-	X	-	L	-	-	-	19
Screech owl	-	-	-	-	-	-	L	-	6
STATE TOTALS	350	481	500	312	575	325	500	481	

Table compiled from data listed in Institute for Land Rehabilitation (1978). The sagebrush vegetation types are from Küchler (1964): Great Basin sagebrush, sagebrush steppe, and wheatgrass-needlegrass shrubsteppe. The symbols X and L were given 12.5 and 6.25 points respectively. The symbols also stand, respectively, for species that occur commonly in vegetation types and species that occur only locally or occasionally in the vegetation type.

as a source of latex rubber (Hall and Goodspeed (1919). The idea was dropped and remained dormant until recently when revived by several researchers (National Science Foundation 1980-82). In the same vein, the rich chemical content of Artemisia species may eventually provide useful products (Kelsey and others 1982).

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IMPROVING THE NUTRITIVE VALUE OF WINTER RANGE FORAGE

Bruce L. Welch

ABSTRACT: The extent of range improvement must be weighed against the increase in quality and/or quantity of the forage available to livestock and wildlife. This paper provides a working knowledge of animal nutrition as an aid in planning and justifying range improvement programs. Major topics are: (1) the digestive tract, (2) nutrient needs of range animals, (3) judging the nutritive values of range plants, and (4) using shrubs to increase the nutritive level of winter ranges.

INTRODUCTION

The purpose of this paper is to discuss techniques for improving the nutritive value of rangeland forage, particularly on winter range. For range plants being grown for animal consumption, nutritive value is of paramount importance, both in quality and quantity. The nutritive value of any plant must be judged in terms of its ability to supply the nutrients needed to meet the physiological requirements of the consuming animal. A basic knowledge of the digestive processes of various kinds of livestock and game is important to understanding their nutrient needs.

THE DIGESTIVE TRACT

By definition, digestion is a process in which food is broken down into smaller particle sizes and finally solubilized for absorption and use in the body (Maynard and others 1979). The digestive tract of an animal includes the mouth, esophagus, stomach, small intestine, and large intestine. Digestive fluids are pumped into the tract from the liver and pancreas. Also located along the digestive tract in the mucus lining are glands that secrete digestive fluids into the tract. Based on the presence or absence of a compound stomach or large cecum, animals can be divided into two great groups: those that can support microbial fermentation to digest highly fibrous foods; and those that lack the ability to support microbial fermentation. Because the most important range animals, from an economic standpoint (cattle, sheep, goats, deer, elk, horses, etc.), have fermentation types of digestion, a detailed discussion of their digestion process is needed.

Bruce L. Welch is Principal Plant Physiologist, Shrub Sciences Laboratory, Intermountain Forest and Range Experiment Station, USDA Forest Service, Provo, Utah.

Animals that can support microbial fermentation can be divided into two groups: those with a compound stomach, called ruminants (cattle, sheep, goats, deer, elk); and those with a simple stomach and a large cecum (horses, rabbits). The ruminant stomach is divided into four compartments: rumen, reticulum, omasum, and abomasum. The rumen is the first and by far the largest of the compartments. Hastily eaten food is stored in the rumen under conditions that favor microbial fermentation and later is regurgitated, thoroughly chewed, and swallowed back to the rumen for additional digestion. Macerated, digested food particles and the bodies of many millions of microorganisms are forced into the reticulum and pass on to the omasum. In the omasum, large quantities of water are absorbed, thus concentrating the macerated-digested food mass and microbial mass. By peristaltic action from the omasum, the food and microbial mass is forced into the abomasum where true digestion begins. Unlike the ruminants where microbial digestion occurs first, in the cecal animals microbial digestion is preceded by regular enzymatic digestion in the stomach (abdomasum) and small intestine.

During the fermentation process volatile fatty acids are formed. These fatty acids, in turn, are absorbed directly by the rumen, or cecum, into the blood stream. Volatile fatty acids are the major supplier of energy to the animal. Through microbial fermentation, the 10 essential amino acids needed by the animal are synthesized by the rumen and cecal microorganisms from plant protein, urea, and inorganic nitrogen. These 10 essential amino acids may occur free in the rumen to be absorbed through the rumen and cecal wall and enter the bloodstream or may be used to build microbial protein which becomes available to ruminant animals through regular enzymatic microorganisms synthesize all the B-vitamins needed by the animal. For animals capable of supporting microbial fermentation, protein quality and B-vitamins are not a concern.

NUTRIENT NEEDS OF RANGE ANIMALS

The quantity of nutrient needed by animals varies according to species, age, size, and activity (National Academy of Sciences 1975, Maynard and others 1979). Qualitatively, nutrient needs of animals can be classified into the following four classes: energy-producing compounds, protein, minerals, and vitamins.

Energy-Producing Compounds

Energy-producing compounds make up the single largest class of nutrients needed by animals (Dietz 1972, National Academy of Sciences 1975). Energy is needed to drive the various physiological processes of the body and to provide movement and heat. Energy can be derived from a variety of compounds, including sugars, fats, pectins, starch, and protein, and in the case of ruminants and others with fermentation abilities, indirectly from cellulose and hemicellulose (Dietz 1972, National Academy of Sciences 1975, Maynard and others 1979).

The energy needs of animals are expressed in several forms such as total digestible nutrients (TDN) and digestible energy. TDN is the sum of all digestible organic compounds (proteins, sugars, cellulose, etc.) with the digestible crude fat component being multiplied by the heat factor 2.25 (Maynard and others 1979). TDN requirements of an animal are expressed as kilograms per animal per day or as a percentage of the diet. Digestible energy (DE) is calculated by subtracting the gross calories in the feed from the calories in the feces (Maynard and others 1979). DE requirements of an animal are expressed as megacalories per animal per day or as megacalories per kilogram of dry matter.

Energy needs of range animals vary according to weight and activity of the animal. Larger animals require more kilograms of TDN per day for a given activity than smaller animals. A lactating female requires more kilograms of TDN per day than a nonlactating female of similar weight. On a constant weight basis, lactation requires more energy than any other activity. In descending order of energy needs, lactation is followed by fattening, growth, gestation, and maintenance (National Academy of Sciences 1975).

Protein

Animal protein makes up a large chemically related, but physiologically diverse, group of compounds. Protein is the major organic compound of the organs and soft tissues of the body. All proteins are made from a common set of building blocks known as amino acids. Proteins are the chief component in a number of bodily structures such as: (1) skeletal muscle for external movement, (2) smooth muscle for internal movement (including passage of food through the digestive tract, breathing, etc.), (3) cardiac muscle for the movement of blood, (4) tendons and ligaments for tying together body parts such as bones, muscles, organs, (5) organs and glands such as the stomach, eye, pituitary, and skin (with its covering of hair), and (6) other structures including hemoglobin, cytochromes, and membranes. Enzymes are another functionally important group of protein compounds. Enzymes provide the frameowrk in which the chemical reactions of the body take place.

Because proteins are involved in so many bodily functions, the animal body needs a liberal and continuous supply. Like energy, the protein requirement of an animal varies according to the weight and activity. For ruminants and other animals that have fermentation-type digestive systems (horses, rabbits, burros, etc.), the quality of the protein is not important--only the quantity of the protein. The protein requirement of an animal is expressed as grams per day of digestible protein or as a percent digestible protein in the diet. Protein requirement may also be expressed as grams per day of crude or total protein or as a percent of crude or total protein in the diet. As with energy, the greater the weight of the animal, the higher the protein needs. This assumes that activity is held constant. Protein needs for the various animal activities with body weight held constant are in the same order as for energy (National Academy of Sciences 1975).

Minerals

About 15 elements are essential for the health of animals. Of these, seven are considered major elements: sodium, chlorine, calcium, phosphorus, magnesium, potassium, and sulfur. The remaining eight are classified as tract elements: iodine, iron, copper, molybdenum, cobalt, manganese, zinc, and selenium. These essential mineral elements constitute the major components of bones and teeth, maintain osmotic relations and acid-base equilibrium, play an important role in regulating enzymatic systems and muscular contraction, and are constituents of most organic compounds. They are also important in energy transfer (Ensminger and Oletine 1978, Maynard and others 1979).

Under most conditions, calcium and phosphorus are the mineral elements of major concern. Animal needs for calcium and phosphorus are expressed as grams per day per animal or as a percentage of the diet. Larger animals under similar activity need greater amounts of calcium and phosphorus than smaller animals. With size held constant lactating animals require the most calcium and phosphorus; followed by growth, fattening, gestation, and maintenance (National Academy of Sciences 1975).

Vitamins

Vitamins are organic compounds the body needs in relatively small amounts. Vitamins are unrelated chemically, but function as metabolic regulators (Maynard and others 1979). For animals capable of supporting microbial fermentation, only vitamin-A is of major concern. Vitamin-A combines with a specific protein of the eye to produce visual purple. In addition to visual purple, vitamin-A plays an important role in normal development of bones, in the normal power of disease resistance, and in maintaining healthy epithelium tissues. Vitamin-A is manufactured from the plant precursor carotene. Therefore, the vitamin-A requirement is expressed in terms of carotene either as milligrams per animal per day or milligrams per kilogram of dry matter. With

size held constant a lactating animal requires the most carotene; followed by growth, fattening, gestation, and maintenance (National Academy of Sciences 1975).

JUDGING THE NUTRITIVE VALUES OF RANGE PLANTS

The nutritive value of a range plant must be judged in terms of how well the plant meets the various nutrient requirements of the consuming animals. Nutritive value can be determined by three means: (1) proximal analysis, (2) *in vitro* digestibility, and (3) *in vivo* digestibility.

Proximal Analysis

Proximal analysis is a series of chemical analyses that determines the crude protein, crude fat, crude fiber, and ash content of a forage on a dry matter basis. A fifth class, called nitrogen-free extract, is determined by nonchemical means by subtracting the percentages of the other components from 100.

Other chemical analyses that are useful in judging the nutritive value of range plants are the percentage of cellulose and lignin. Although the chemical makeup of range forages indicates probably nutritive value, digestibility is the major criterion, when judging the ability of a forage to meet the nutrient needs of an animal.

In Vitro and *In Vivo* Digestibility

Digestibility can be determined by *in vitro* (outside the animal's body) or *in vivo* (in the animal's body) means. *In vitro* digestibility is a laboratory technique that simulates natural ruminant digestion. The results are expressed as a percentage of dry matter digested (Pearson 1970). The main advantages of *in vitro* digestibility techniques are its simplicity, speed, precision, and low cost. The main disadvantage is that the digestibility of individual nutrients (i.e., crude protein) is unknown.

The *in vivo* digestibility technique consists of feeding the forage of interest (usually alone) and collecting the feces. Through chemical means, the amount of nutrients being consumed by the test animals and being excreted in the feces is known. The difference between the two would represent the portion of the nutrients in the forage digested by the animals. Results of *in vivo* digestibility trials are expressed as digestion coefficients of the various proximate analysis classes of crude protein, fat, fiber, nitrogen-free extract, and as total digestible nutrients. Total digestible nutrients is an estimate of the digestible energy of a forage. Total digestible nutrients is a sum of all the digestible organic nutrients (protein, fiber, nitrogen-free extract) with the digestible fat fraction multiplied by the energy factor 2.25.

The main advantage of the *in vivo* digestibility technique is a complete knowledge concerning the digestibility of individual nutrients. Its main advantage is cost and time.

Factors Affecting the Nutritive Values of Range Plants

Factors that affect the morphology and metabolism of range plants also affect nutritive value. These factors include climate, soil, and genetic factors. These factors usually express themselves in influencing the speed of the phenological development. In general, the nutritive values of range plants peak in the spring and then decrease, reaching a low level during the dormant season (Urness 1980). This is illustrated in table 1. For all three range plants: big sagebrush (*Artemisia tridentata*), antelope bitterbrush (*Purshia tridentata*), and unknown grass, the crude protein content was highest during the spring and lowest during the winter. The two shrubs seem genetically coded to maintain (through the dormant season) a greater crude protein content than grass. Big sagebrush dry matter contains higher winter levels of crude protein than antelope bitterbrush (Welch 1981, table 1). It has been reported that accessions of big sagebrush, antelope bitterbrush, and fourwing saltbush (*Atriplex canescens*) grown on a common garden vary significantly in mid-winter content of crude protein (Welch and McArthur 1979, Welch and Monsen 1981, Welch and others 1983). Also, genetic factors play an important role in big sagebrush digestibility, preference, and growth rates (Welch and others 1981, Welch and Pederson 1981, McArthur and Welch 1982).

Table 1.--Seasonal variation in crude protein content of three range plants, dry matter basis (data from Tueller 1979).

	Forage		
Date	Big sagebrush	Antelope bitterbrush	Grass
6/68	11.8	13.4	13.4
7/68	12.7	12.8	7.8
9/68	11.8	9.7	9.6
12/68	10.5	7.5	2.7
2/69	14.0	9.9	3.4
5/69	15.0	11.3	21.3

USING SHRUBS TO INCREASE THE NUTRITIVE VALUE OF WINTER RANGES

Some range plants supply certain winter nutrients below the level needed by the consuming animal (Urness 1980). In general, three nutrients are in short supply in winter forages (Dietz 1965). These nutrients are energy (TDN), protein, and phosphorus. The following discussion will demonstrate that palatable shrubs can increase the nutritive value of winter ranges for livestock and wildlife.

Total digestible nutrient requirements for wintering a 150-pound ewe (maintenance) is 55 percent of dry matter consumed (National Academy of Sciences 1975). The nutritive needs of wintering mule deer have not been determined. Because of the similarity in the digestive tract and eating habits of mule deer and sheep, it is assumed that the nutritive needs of wintering mule deer are similar to sheep. Table 2 lists the amount of TDN in winter shrubs and grasses as determined with mule deer and sheep. Evergreen shrubs (curlleaf mahogany, big sagebrush, and juniper) and two grasses (sand dropseed and western wheatgrass) supply enough TDN to exceed the 55 percent requirement. In general, grasses are higher in winter levels of TDN than shrubs (Cook 1972, Welch 1981) although it is evident from the data in table 2 that certain evergreen shrubs supply as much or more winter-level TDN as grasses.

Table 2.--The amount of total digestible nutrients in winter forages. Data expressed as percentage of dry matter (table adapted from Welch 1981)

Forages	Total digestible nutrients[1] (percent)	Reference[2]
Curlleaf mahogany	64.8	1,2,3
Big sagebrush	61.3 (58.8)[3]	1,2,3,4,5,6,7
Juniper	60.8 (52.9)[3]	2,3
Sand dropseed	59.0	6,9
Western wheatgrass	57.6	6,8,9
True mahogany	48.4	1,2,4
Indian ricegrass	48.2	6,9
Bitterbrush	46.0	1,2,3,5
Needle-and-thread	45.1	6,8,9
Winterfat	40.0	6,8,9
Chokecherry	38.9	2
Gambel oak	36.2	2
Nuttall saltbush	36.0	9
Shadscale	31.0	9

[1]The total digestible nutrient requirements for wintering sheep, and probably mule deer, are 55 percent (National Academy of Sciences 1975).

[2] 1 = Urness and others 1977 - deer; 2 = Smith 1957 - deer; 3 = Smith 1952 - deer; 4 = Dietz and others 1962 - deer; 5 = Bissell and others 1955 - deer; 6 = Cook and others 1954 - sheep; 7 = Smith 1950 - deer; 8 = Morrison 1961 - sheep; 9 = National Academy of Sciences 1964 - sheep.

[3]Values in () corrected for presence of monoterpenoids (Welch and McArthur 1979).

According to the National Academy of Sciences (1975), the digestible protein requirement for wintering sheep, and probably mule deer, is 4.8 percent of dry matter consumed. Table 3 lists the winter content of digestible protein of shrubs and grasses determined with mule deer and sheep. Fourwing saltbush, winterfat, big sagebrush, and curlleaf mahogany (all evergreen shrubs) exceed the digestible protein requirement.

Table 3.--The amount of digestible protein in winter forages. Data expressed as percentage of dry matter (table adapted from Welch 1981)

Forage	Digestible protein[1] (percent)	Reference[2]
Fourwing saltbush	8.2	1
Winterfat	6.7	1,3,8,9
Big sagebrush	6.0	2,3,4,5,6,9
Curlleaf mahogany	5.9	5,7
Black sagebrush	4.5	3,9
Shadscale	4.3	3,9
Nuttall saltbush	3.4	3
Mountain mahogany	3.4	2,5
Bitterbrush	3.3	2,4,5,7
Sand dropseed	1.2	3
Needle-and-thread	1.2	3,9
Western wheatgrass	.5	1,3,9
Indian ricegrass	.2	3,9

[1]The digestible protein requirements for wintering sheep and probably mule deer, are 4.8 percent (National Academy of Sciences 1975).

[2] 1 = Otsyina and others 1980-sheep; 2 = Dietz and others 1962-deer; 3 = National Acad. of Sci. 1964-sheep; 4 = Bissell and others 1955-deer; 7 = Smith 1952-deer; 8 = Morrison 1961-sheep; 9 = Cook and others 1954-sheep.

Black sagebrush and shadscale, also evergreen shrubs, supply digestible protein just below the requirement of 4.8 percent. The semi-evergreen Nuttall saltbush (this term in the Publications Cited is better referred to as Gardner saltbush [Stutz and others 1979]) and the deciduous shrubs, such as bitterbrush and mountain mahogany, supply digestible protein well below the requirement.

Dormant grasses, such as sand dropseed, needle-and-thread, western wheatgrass, and Indian ricegrass are even lower in digestible protein than the deciduous shrubs. In general, shrubs are higher in winter levels of digestible proteins than are grasses (Cook 1972, Welch 1981).

The calcium and phosphorus requirements for wintering sheep, and probably mule deer, range

Table 4.--The amount of calcium and phosphorus in winter forages; data expressed as percentage of dry matter.

Forage	Phosphorus[1]	Calcium	Reference[2]
	percent	percent	
Aspen	0.23	--	6
Big sagebrush	.22	0.65	1, 2, 3, 4, 5, 7, 8
Juniper	.19	1.20	1, 4, 5
Chokecherry	.18	--	5, 9
Curlleaf mahogany	.17	--	5, 8
Black sage	.17	.62	2, 3, 4
Saskatoon serviceberry	.17	--	5, 9
Fourwing saltbush	.15	1.19	4
Nuttall saltbush	.15	2.56	2, 3, 4
Bitterbrush	.13	.68	1, 4, 5
Mountain mahogany	.13	.73	1, 7
Winterfat	.12	2.10	2, 3, 4
Shadscale	.11	2.44	2, 3, 4
Desert bitterbrush	.10	--	5
Needle-and-thread	.07	.67	2, 3, 4
Western wheatgrass	.07	.67	2, 3, 4
Sand dropseed grass	.07	.48	2, 3, 4
Indian ricegrass	.06	.54	2, 3, 4

[1]The calcium and phosphorus requirements for wintering sheep and deer range from 0.25 to 0.35 percent and 0.18 to 0.28 percent, respectively (National Academy of Sciences 1975).

[2]1 = Dietz and others 1962, 2 = National Academy of Sciences 1964, 3 = Cook and others 1954; 4 = National Academy of Sciences 1958, 5 = Tueller 1979; 6 = Tueller 1979, 6 = Short and others 1982; 7 = Medin and Anderson 1979 (data converted to dry-matter basis), 8 = Trout and Thiessen 1973; 9 = Dietz 1972.

from 0.25 to 0.35 percent and 0.18 to 0.28 percent, respectively, of dry matter consumed (National Academy of Sciences 1975). Table 4 lists the winter content of calcium and phosphorus for selected range plants. All forages listed supply calcium well above the needs for the wintering animals. None of the forages listed meets the upper requirement for phosphorus. Only five of the forages (all shrubs) meet the lower range of the phosphorus requirement. In general, shrubs are higher in winter levels of phosphorus than are grasses (Cook 1972, Welch 1981).

The winter diets of range animals are not usually considered deficient in carotene. Based on data in table 5, however, range animals consuming large amounts of dormant grass could easily develop a vitamin-A deficiency. All the shrubs listed in table 5 supply carotene at a level many times above the carotene requirement of wintering sheep, and probably mule deer (1.8 mg/lb) (National Academy of Sciences 1964). In general, shrubs supply higher winter levels of carotene than grasses (Cook 1972, Welch 1981).

It is apparent that palatable shrubs can increase the amount of protein, phosphorus, and carotene on winter ranges for livestock and wildlife. Also, certain evergreen shrubs can increase the amount of TDN on winter ranges.

Increasing the density of palatable shrubs by one or more of the techniques available can effect a dramatic improvement in the nutritive value of range forage.

Table 5.--The amount of carotene in winter forages. Data expressed as milligrams per pond of dry matter (table adapted from Welch 1981).

Forage	Carotene[1]	Reference[2]
	mg/lb	
Shadscale	10.0	1,2
Nuttall saltbush	8.6	1
Big sagebrush	8.2	1,2
Black sage	8.0	1,2
Winterfat	7.6	1,2
Sand dropseed	.6	1,2
Western wheatgrass	.3	1,2
Needle-and-thread	.2	1
Indian ricegrass	.2	1,2

[1]The carotene requirement for wintering sheep, and probably mule deer, is 1.8 mg/lb (National Academy of Sciences 1964).

[2]1 = National Academy of Sciences 1964;
2 = National Academy of Sciences 1958.

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Section 5. Management Practices

EVALUATION OF MANAGEMENT AS A FACTOR IN THE SUCCESS OF GRAZING SYSTEMS

W. A. Laycock

ABSTRACT: The literature on grazing systems on rangelands is confusing and contradictory, especially concerning the effects of continuous grazing versus specialized grazing systems. This paper evaluates the role of all aspects of management in the success or failure of grazing systems. Management (fencing, water development, undesirable plant control, and factors influencing animal distribution) taken as a whole may be the key to success or failure of any particular grazing system and the grazing controls (timing and intensity of grazing) may have little additional effect.

INTRODUCTION

The literature on the effects of different grazing systems on herbage yield, range condition, and livestock performance is confusing and, in many cases, contradictory. The only general concensus seems to be that almost any system is better than heavy continuous or heavy season-long use for most range types, but there may be exceptions. Too often a grazing system has been applied because it worked elsewhere, because an agency is committed to using the system elsewhere, or for no reason at all. For example, in the 1960's and 1970's "rest-rotation" became the system for Forest Service and BLM allotments throughout the West. This system, originally designed for an Idaho fescue (*Festuca idahoensis*) bunchgrass-type range, has been widely expanded into other vegetation types with varying success. Rest-rotation systems have been proposed or applied to vegetation types where the physiology or life cycle of the dominant plant species makes such a system inappropriate, such as ranges dominated by cheatgrass brome (*Bromus tectorum*) or seeded to crested wheatgrass (*Agropyron cristatum* or *A. desertorum*).

The grazing system or method for the 1980's seems to be "short duration grazing" (Savory 1978) or the "Savory grazing method" (Savory and Parsons 1980). In the United States, most applications of this have been in the Southwest, but both research and on-the-ground applications are increasing throughout the West.

W. A. Laycock is a Range Scientist with the USDA, Agricultural Research Service, Crops Research Laboratory, Colorado State University, Fort Collins, Colo.

What is a grazing system? A glossary published by the Society for Range Management (1974), contains these definitions:

> GRAZING MANAGEMENT: The manipulation of livestock grazing to accomplish a desired result.
>
> GRAZING SYSTEM. A specialization of grazing management which defines systematically recurring periods of grazing and deferment for two or more pastures or management units.

Vallentine (1979) proposed that the term "grazing system" be restricted to seasonal patterns of grazing rather than used as a description of day-to-day provisioning of livestock feed. Vallentine presented two major misconceptions about grazing systems: (1) a universal grazing system exists; and (2) specialized grazing systems are the long-awaited panacea that will permit ignoring the other principles of grazing management. He further stated that, unless the confines of the feasible or realistically maximum season of grazing are first established, the effective application of any grazing system will be thwarted.

A main problem with much of the research on grazing systems and their application has been that other principles of good range management were not considered important to the outcome or their effects were not measured. In actual practice all or some of the following management tools usually are applied in addition to the regulation of grazing: fencing, water development, seeding, brush control, fertilizing, salt distribution, and intensified animal husbandry to improve distribution.

An exception to the lack of understanding or consideration of the role of management in the success or failure of a grazing system may be the Savory grazing method. It is applied in conjunction with what is termed "holistic ranch planning" (Savory and Parsons 1980). However, this planning concentrates on total ranch and business management more than on the evaluation of the specific management tools (fencing, water development, and so forth) that must be applied before the grazing system is started.

This paper evaluates the role of all aspects of management in the success or failure of grazing systems. Many reviews that compare two or more grazing systems will be examined to determine the degree that management has played as part of a grazing system.

CHARACTERISTICS OF SUCCESSFUL GRAZING SYSTEMS

Hyder and Bement (1977) stated that the following should be required in planning a grazing system: (1) stocking rates that will achieve moderate grazing during the growing season to obtain good herbage production; (2) occasional rest during the growing season; and (3) occasional heavy grazing when plants are dormant to reduce ungrazed plants and promote more uniform grazing.

Vallentine (1979) suggested that the following are minimal characteristics of an effective grazing system:

1. The system must be based on the physiological requirements and life history of the primary forage plants and be suited to them.
2. It will improve condition on low-condition range or maintain high-condition range.
3. It is adapted to existing soil conditions, and erosion and puddling will not result from its use.
4. The system is not detrimental to animal gain and will minimize disturbance of livestock.
5. It must be economically sound; range improvement may be slow and the cost of additional fencing and stockwater development may be high.
6. The system must be practical to implement, reasonably simple to operate, and flexible enough to meet fluctuations in forage production caused by weather.
7. The system must fit in with the total grazing management plan for the ranch, operational unit, or allotment.

In a little-cited paper, Heady (1974) presented the beginning of a theory for seasonal grazing. Except for some areas in the Southern United States, seasonal grazing is what is important when we discuss grazing systems. Heady outlined the objectives of seasonal grazing:

> Grazing during a certain time period aims for one or more of the following: (1) rehabilitation of range condition and soil stabilization, or maintenance of ecosystems in satisfactory condition; (2) sustained high animal production; (3) efficient use of all available feed (We seldom see that objective in our literature but South African literature often starts with it as the headline.); (4) a way to keep more animals (That one, too, we only occasionally hear.); and (5) a dense cover of the palatable species and reduction of the unpalatable species by reducing selective grazing. All but the first aim at maximum livestock production and give emphasis to the needs of animals.

Heady (1974) proposed that, if a range manager had the answers to the following questions, he could put together a logical grazing schedule or grazing system: (1) When does defoliation do the most harm and when is the greatest plant response without defoliation? (2) What are the criteria for taking animals out of a pasture and for selecting the pasture into which they are placed? (3) What is the ideal length of the grazing period and the span of time without grazing? Heady stated that very few answers to these questions exist for specific areas and at the scale of practical grazing schedules.

Until we can more completely answer these questions, increasing our knowledge of the effect of all management factors will be more productive than searches for specific grazing systems to solve our range management problems.

We do have partial answers to some of the questions for some species, but this knowledge is often ignored by managers. A case in point is crested wheatgrass. Studies in Saskatchewan (Lodge and others 1972), Utah (Frischknecht and Harris 1968), Idaho (Sharp 1970), New Mexico (Springfield 1963), and other places indicate that crested wheatgrass can be grazed rather heavily every year without causing damage to the stand. Some studies also point out the definite utilization and cattle gain problems that result from letting crested wheatgrass grow to maturity ungrazed. In spite of this, some public land managers have recommended rest-rotation grazing fifty percent or less utilization for crested wheatgrass.

OTHER COMPARISONS OF GRAZING SYSTEMS

As mentioned, the literature on the effects of different grazing systems are varied and inconsistent. Hickey (undated, about 1967) reviewed 49 research papers published between 1895 and 1966. He reached the following conclusions about some specific grazing systems:

<u>Rotation of four pastures or more</u>: Available literature was insufficient to support definite statements.

<u>Deferred grazing</u>: Rate of improvement appears to be related to frequency and duration of rest.

<u>Deferred rotation and rotational deferment</u>: There were too few research papers to support conclusions.

<u>Rest-rotation</u>: "All authors appear to agree that this is the best long-range grazing system from all aspects of the livestock industry. This method appears to offer the greatest net returns per dollar of investment." However, Hickey reviewed only six rest-rotation studies, three of which were progress reports from the original study at Harvey Valley, California.

Driscoll (1967) examined 50 reports of studies comparing livestock and vegetation responses under continuous grazing versus some other system. Based on 29 reports, livestock weight gains were greater under continuous grazing in 12 studies, greater in special systems in 8 studies and not different between systems in 9 studies. In 39 reports comparing responses of desirable species of vegetation, only 3 indicated improvement of vegetation under continuous grazing while 31 indicated decline of condition under continuous grazing compared to some other system; 5 studies showed no difference. Driscoll concluded: "It is apparent from this review that some system of grazing other than continuous or season-long will probably be needed to improve the vegetal condition of most rangelands."

More recent reviews of research reach conclusions somewhat different from those of Hickey and Driscoll. Shiflet and Heady (1971) reviewed published studies on specialized grazing systems in the United States but did not necessarily make comparisons with continuous grazing. They concluded that specialized grazing systems vary from highly successful to totally unsuccessful. Some systems improved vegetal cover or production but not livestock production, others increased livestock production with no effect on the vegetation, and a few improved both vegetation and livestock.

Herbel (1974), in a review of grazing systems on native ranges of the Western United States, found that any grazing system other than continuous had only limited success on rangelands grazed only part of the year (seasonal ranges). Herbel further concluded that "most studies have shown that livestock production per animal is the same or lower for a rotational system compared to continuous grazing."

In a review article that has received little attention in the United States, Gammon (1978) reviewed 62 published studies comparing systems of grazing management, not only in the United States but in South Africa, Rhodesia, and other countries. He reviewed the claims made of the benefits to be derived from various rotational methods of grazing management, including increase in herbage yield, increase in pasture condition, and increase in grazing capacity and output of animal products. He concluded that "many or most of the claims were extravagant or unsubstantiated." Gammon found that fewer than half of the studies comparing rotational systems to continuous grazing reported pasture improvement relative to continuous grazing. In the majority of the experiments, animal production in the rotational systems was either similar to or poorer than achieved under continuous grazing. No rotational system consistently resulted in improved pasture conditions or increased animal production. However, Gammon did indicate that some form of rotational grazing may be desirable but that no conclusive experimental evidence indicates superiority of one form of rotational management over any other, and that systems with eight or more paddocks provide little or no advantage over systems with fewer paddocks.

REASONS FOR LACK OF AGREEMENT IN RESULTS OF GRAZING STUDIES

Gammon (1978) detailed the factors he felt caused the disparity in results of grazing management experiments. These are presented below with information from other sources added where appropriate.

Failure of Experiments to Reveal Potential Differences

Limitations of Design--Improper experimental design, including lack of replication, inadequate data collection, and improper use of statistics are common problems in grazing studies. In many studies, grazing and rest periods have been unrealistically rigid, paddocks have been too small, and duration of the studies has been insufficient to reveal long-term effects. Examples of the failure to recognize the difficulty of interpreting short-term results from grazing experiments abound in the literature. Ratliff and others (1972) cited an example of "10 percent increase in the allowable number of cattle after only one year of rest-rotation grazing. This was on a range grazed yearlong and with only 9 inches of precipitation annually." Laycock and Conrad (1981) pointed out that no system can be evaluated after only one year to determine if it has increased carrying capacity, especially in a low rainfall area where vegetation responses tend to be very slow.

Stocking rates too low--Potential differences between grazing systems are more likely found at relatively high stock rates than at the moderate or light rates that have been used in many experiments.

Limitations to Pasture Management Concepts

Physiological superiority of certain systems--Gammon (1978) found evidence that the assumptions that certain grazing systems are physiologically favorable to desirable plants are often invalid. Furthermore, some studies indicate that the root reserve theory basic to most rotational grazing systems may be unsound or at least less important than was previously believed.

Defoliation effects--Effects of different levels or times of defoliation have been evaluated, mainly in clipping studies, and the differences

in response from clipping versus grazing have been shown in many studies. Mueggler (1970, 1972) compared effects of clipping under reduced or no competition as well as under full competition. One year after severe clipping, bluebunch wheatgrass (Agropyron spicatum) plants under no competition yielded more than unclipped plants under full competition. These results raise serious questions about the validity of many clipping studies, most of which have been conducted under conditions of complete protection from grazing and thus under full competition from surrounding vegetation.

Seeding and seedling establishment after rest.--Although this has been an important part of many grazing systems in the United States and South Africa, only two of the experiments reviewed by Gammon (1978) presented information on seed dispersal and establishment of seedlings following rest. Both studies indicated that no natural re-seeding took place. In support of this, Hyder and others (1975) stated that "attempts to duplicate nature by broadcasting seeds of native dominant perennial grasses on untilled, depleted rangeland, with or without trampling, have failed. Even on tilled soils, broadcasting of seed generally is a waste of time on semiarid rangelands."

Patterns of defoliation during grazing.--The assumption that defoliation patterns during grazing are clearly different between rotational and continuous grazing may not be true in correctly stocked pastures. Several studies reviewed by Gammon (1978) did not confirm the popular concept that frequent, severe defoliation takes place under continuous grazing; individual plants or areas within continuous grazed pastures were grazed neither continuously nor heavily. This was confirmed by Hart and Balla (1982) in studies in Wyoming. Using time-lapse photography, they determined that grazing of individual tillers of western wheatgrass (Agropyron smithii) was relatively infrequent even under continuous grazing and that up to 50 percent of individual tillers remained ungrazed or grazed only once during a 10-week grazing season.

Selective grazing.--A common approach to the problem of selective grazing is to increase stocking for short periods to induce grazing of the less palatable plants. This forced grazing usually results in extreme defoliation of the palatable species. If the heavy grazing is for a short period and not repeated at the same time year after year, it may not be detrimental to the plants, but livestock performance probably will suffer.

Stocking intensity.--In grazing management, the benefit of rest can only be provided by increasing stocking density in the paddocks being grazed. Gammon (1978) stated that "it is a common false assumption that rest or deferment can compensate for overuse or for previous critical season use, regardless of conditions." This was borne out on the arid rangelands of the Arizona strip where Hughes (1979) found that any system of grazing, including rest-rotation, caused deterioration of the vegetation when utilization exceeded 55 percent. This presumably was because the rest cycle was not long enough to compensate for the damage caused by heavy use.

Management practices not uniformly applied.--Failure to evaluate the level of other management factors in any comparison of grazing systems may cause misleading results. (This is the major point of the present paper and it will be discussed further below.)

DISCUSSION

The importance of range improvement practices and increased level of management in the success of a grazing system has been recognized in the literature, but no specific evaluations of their role have been made. Shiflet and Heady (1971) in their review of specialized grazing systems stated:

> Numerous other benefits are attributed occasionally to specialized grazing systems. They are said to improve distribution of animals, to prevent selective grazing, to foster closer supervision of livestock, and to permit incorporation of range improvement practices in the range management program, such as planned burning schedules, brush control, reseeding, and protection of new seedlings. Although these practices are or can be fostered by a grazing system, they do not require specialized grazing systems. They are valuable range improvement practices in themselves.

Herbel (1974) stated:

> When a rotation scheme is initiated, range improvements such as seeding, brush control, fencing, and water developments are often not properly credited for observed differences when compared to unimproved ranges. Rather, there is a tendency to credit the rotation scheme for observed improvements in range condition or animal performance. Any improvement that aids livestock distribution will result in greater productivity.

In a study conducted on high-elevation sagebrush-grass ranges in Utah, Laycock and Conrad (1981) found no differences in individual cattle gains or vegetation response between continuous summer-long grazing (July 1-Sept. 30) and a three-unit rest-rotation system over a 7-year period. Pastures in both grazing systems had adequate

and well-distributed water, good distribution of salt, and adequate dispersal of cattle with riding. The lack of difference between the two systems was because both had the same level of intensive management.

I contend that the level of management is the key to success or failure of any particular grazing management scheme and that the grazing controls imposed may have little additional effect. When a grazing study is conducted or a grazing system is put on the ground, the level of good range management invariably is increased substantially. If the level of overall management is the key to success of a grazing system and not simply the timing of grazing, this may be the reason many studies show no differences between grazing systems. It also may be why so many range managers are happily surprised at the positive results they get when they institute a grazing system.

In many situations when a particular grazing system is to be applied, fences are built, water is developed, and salting, riding, and other management is intensified. Then, if a favorable response in the vegetation is detected, the tendency is to say--"Look what this grazing system has done for the range." In reality, the proper statement is--"Look what good management (or good range management) has done." Range managers should apply grazing systems that produce the most red meat in the most economical manner, while preserving the productivity, watershed, open space, wildlife values, and other attributes of ranges in good condition. If the best system for a given range type is a relatively complex one (rest-rotation, short duration, and so forth,) then it should be used. If a simpler system (continuous, simple deferment, or others) gets equally good or better results, then it should be used.

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STAND DYNAMICS AND MANAGEMENT ALTERNATIVES FOR PINYON-JUNIPER WOODLANDS

Richard O. Meeuwig

ABSTRACT: Pinyon-juniper woodlands occupy more than 50 million acres (20 million ha) in the western United States. During the 19th century, vast areas around mining towns and other settlements were clearcut for firewood, charcoal, and other products. The woodlands have been extensively grazed for more than 100 years, but the forage resource has declined drastically as trees have reoccupied the cutover areas and have moved into adjacent fire subclimax communities. Management alternatives include: complete tree removal with or without seeding to grass, management for sustained yield of fuelwood and other woodland products, and custodial management with or without fire protection. Management decisions for each stand should be based on present and future resource demands, present and projected stand characteristics, site characteristics, probability of successful conversion, and costs of conversion and maintenance in relation to expected benefits.

INTRODUCTION

The pinyon-juniper woodland type covers more than 50 million acres (20 million ha) in the western United States, mostly in Nevada, Utah, Arizona, New Mexico, Colorado, and California. In addition, the western juniper type covers several million acres in Oregon and neighboring states. Western juniper is usually considered a separate cover type, but it is similar to the pinyon-juniper type in many ways.

Pinyon-juniper woodlands grow on a wide variety of soils including Mollisols, Aridisols, Entisols, Alfisols, and Vertisols. Pinyon-juniper grows on most well-drained landforms. The lower elevational limits are defined by one or more of the following conditions: (1) marginal soil moisture, (2) poorly drained soil, (3) salt accumulation, or (4) atmospheric temperature inversion. The upper elevational limits are usually defined by competition from more tolerant species or by temperature regime. Elevations usually range from 4,500 to 8,000 ft (1 400 to 2 400 m), but pinyon has been reported as low as 2,000 ft (600 m) and as high as 10,000 ft (3 000 m).

Products and Past Use

Pinyon-juniper woodlands provide a variety of products. Pinyon nuts were a major source of food for Indians for many centuries and are still harvested extensively. Throughout the Southwest, pinyon-juniper woodlands have been major sources of fuelwood, fenceposts, and Christmas trees. The woodlands supplied most of the charcoal and fuelwood for the booming mining industry in the Great Basin during the latter half of the 19th century (Young and Budy 1979). Vast areas around mining towns and other settlements were clearcut. Throughout the rest of the woodlands most stands have been high-graded, leaving residual stands of poor-form trees and inferior species.

After the turn of the century and until the energy crisis of the early 1970's, the availability of cheap fossil fuel took the pressure off the pinyon-juniper woodlands as a source of fuelwood. As tree harvesting declined, the woodlands began to recover. The partially cut and clearcut areas became restocked with trees and, because of fire control during this time period, pinyon and juniper moved into adjacent communities where recurring fires had previously excluded them.

Since the mid-1970's, the rapidly rising costs of fossil fuels have caused a resurgence of fuelwood cutting in the woodlands. The unexpected increase in demand for fuelwood has already created shortages around several urban areas (Gray and others 1982) and future demands may exceed production over most of the pinyon-juniper type.

The woodlands have been grazed by livestock for more than 100 years and some parts around the old Spanish settlements in New Mexico have been grazed for as long as 400 years. All too often, grazing was continuous and excessive, resulting in deteriorated range conditions (Springfield 1976). Grazing on most pinyon-juniper ranges has been brought under management in the past 70 years, but recovery of the range has been slow. The forage resource has declined drastically as trees reoccupied cutover areas and moved into adjacent shrub and grass communities.

In the past 35 years, extensive areas of pinyon-juniper have been clearcut, cabled, chained, crushed, or burned to increase forage production for livestock and big game. Some of these conversion projects were successful, but many others failed to increase carrying capacity for more than a few years, and the treated areas have been reoccupied by young juniper and pinyon trees.

As a result of past use, the pinyon-juniper stands of today consist mainly of four general types:

1. A few virgin stands in remote areas or on poor sites.

Richard O. Meeuwig is Project Leader at the Intermountain Forest and Range Experiment Station, USDA Forest Service, Reno, Nev.

2. Old high-graded stands containing various proportions of old, poorly formed trees, trees between 100 and 200 years old that were too small to cut when the stands were harvested in the 19th century, and trees less than 100 years old that came in after harvest.

3. Young stands that have reoccupied areas where virtually all trees had been eliminated either by heavy harvesting or type conversion efforts.

4. Young stands that have invaded adjacent communities because of fire protection.

GROWTH AND PRODUCTIVITY

Although large amounts of wood have been harvested from pinyon-juniper woodlands, little thought has been given to managing the type for sustained yield of wood and there has been little research on the growth characteristics of pinyon and juniper. A number of studies of growth and yield were made shortly before World War II but research on this subject was not resumed until about 7 years ago. Recently we have studied pinyon and juniper growth in a number of stands in Nevada and California using stem analysis techniques (Meeuwig and Budy 1979; Meeuwig 1979). Results of these studies led to the following conclusions:

1. Diameter growth rates are not directly related to tree age but are regulated primarily by competition. Some trees in dominant positions have maintained essentially constant diameter growth for more than 100 years.

2. Height growth rates can vary widely among trees in the same stand, particularly in old, unevenaged stands. Yet each tree grows in height at a fairly constant rate throughout most of its life. Some trees were found to have maintained constant height growth for more than 100 years. Reduction in height growth rates appears to be caused not by age directly but by approach to a site-specific maximum height.

3. Once a pinyon-juniper stand fully dominates a site, the basal area growth of that stand becomes remarkably constant. The rate of basal area growth of such fully stocked stands appears to be independent of stand structure but varies from site to site and can therefore be expected to be a good index of site quality.

4. Fuelwood volume growth rates continue to increase to some extent after basal area growth has attained a constant maximum. Volume growth rate was still increasing on all the study plots, even the oldest plot where half of the trees were more than 240 years old.

In another study we measured basal area growth, aboveground biomass accumulation rates, and fuelwood production in 103 fully stocked stands scattered across Nevada and in adjacent parts of California (Meeuwig and Cooper 1981). Basal area growth varied from 0.4 to 2.4 ft^2/acre/year (0.1 to 0.6 m^2/ha/yr) and averaged 1.1 ft^2/acre/year (0.3 m^2/ha/yr). Aboveground biomass accumulation rates were highly correlated (r=.91) with basal area growth ranging from 240 to 1,860 lbs/acre/year (270 to 2 080 kg/ha/yr) and averaging 800 lbs/acre/year (900 kg/ha/yr). These figures are annual increases in aboveground biomass and do not include understory vegetation, cone and litter fall, or belowground biomass.

Average annual increment of fuelwood on these fully stocked plots ranged from 6 to 30 ft^3/acre (0.4 to 2.1 m^3/ha) and averaged 17 ft^3/acre (1.2 m^3/ha). In other words, the average fully stocked stand in our sample takes about 5 years to grow a cord of wood per acre. Fuelwood volumes on these plots averaged 14 cords per acre (73 m^3/ha) and ranged from 2 to 28 cords per acre (10 to 145 m^3/ha). These figures are for fully stocked stands; the average yield would be much smaller if young understocked stands were included in the sample. For example, Howell (1941) found that gross annual increment averaged 0.14 cords/acre (0.7 m^3/ha) on sample plots in northern Arizona and New Mexico.

Results of this study were used to develop a model relating potential basal area growth to topography and parent material. In general, the model showed that growth is poorest on steep south-facing slopes and best on north-facing slopes steeper than 20 percent. No direct relationship between elevation and growth was detected. Growth was better on soils derived from igneous rocks than on limestone soils.

MANAGEMENT ALTERNATIVES

Alternatives for managing pinyon-juniper woodlands are:

1. Type conversion for wildlife or livestock range.

2. Management for sustained yield of fuelwood and other woodland products.

3. Custodial management where neither of the other two management alternatives is cost effective.

Type Conversion

Type conversion is the destruction of existing vegetation or at least of unwanted dominant species to improve forage production either by seeding wanted species or by releasing preferred but suppressed understory.

Chaining is the most commonly used method of type conversion. Seeding is almost always necessary in chaining projects. If the understory is good enough to respond adequately to tree removal, the trees are probably small or widely scattered and could be removed more cheaply by some other method. Chaining uproots and kills the larger trees but the smaller trees, particularly junipers, usually survive. These survivors should be eliminated in some way for an efficient conversion. If they are left in place, they will outcompete the forage species and form the nucleus of a new pinyon-juniper stand.

Aro (1971) found that single-chaining killed an average of only 38 percent of the trees. Double-chaining was more effective, killing an average of 60 percent. But, even with double-chaining, about 40 percent of the trees remain and would redominate the site in as little as 15 years (Tausch and Tueller 1977) if not controlled.

Aro (1971) found that windrowing after chaining killed at least 95 percent of the trees but is quite expensive. Prescribed burning was equally effective in killing trees. Burning and windrowing may kill most of the understory vegetation and may not necessarily improve the range if seeded species do not establish properly.

Prescribed burning works best in open stands that still have enough understory to carry fire, especially where the understory is dominated by grasses rather than shrubs. Prescribed burning may be used as a followup treatment on chained areas to eliminate the debris and to kill the surviving trees. Such areas may respond best if burned several years after chaining when the seeded grasses are well established.

Hand cutting has been used in some areas. Arnold and others (1964) reported that Fort Apache Indians used hand axes extensively to clear 95,000 acres (38 000 ha) in New Mexico. Chain saws are being used to eradicate western juniper in Oregon (Winegar and Elmore 1978).

In scattered stands of small trees (old burns, old chained areas, other treated areas, and invasion areas), individual trees may be killed by burning when the fire danger is low, by herbicides applied by hand (Evans and others 1975), or by cutting with an axe, brush bar, or lopping tool. This type of treatment would retard the invasion and domination process without damage to the understory. As tree density and size increase, the costs of individual tree control increase and some other method such as broadcast burning might be more appropriate.

Of course, a careful economic analysis of costs and benefits should be made before any conversion project is undertaken. As much as possible, *all* costs and *all* benefits should be considered. Management decisions for each stand should be based on present and future resource demands, present vegetation and site characteristics, loss of wood production, probability of successful conversion, costs of conversion and maintenance, and probable value and characteristics of the converted stand.

In each locality where forage for livestock or wildlife must be increased within the pinyon-juniper woodlands, we should look first at the open stands, ecotones, and natural openings where the fewest and smallest trees would need to be eliminated to maintain adequate forage production. Treatment and maintenance costs would be lowest on such sites and the impact on fuelwood production would not be as great as it would be in more advanced pinyon-juniper stands.

Sustained Yield

Until now, pinyon-juniper woodlands have not been managed in accordance with silvicultural principles, except in a few isolated instances. Only 20 years ago, hardly anyone suspected that the demand for fuelwood would be as great as it is today. The wood resource was not considered to be worth very much and was often considered a liability. The type conversion activities of the past 30 years or so have destroyed a significant part of the fuelwood supply in many localities. Of course, much of the wood was salvaged on the conversion areas but most of these areas, even those where the conversion efforts failed, will not regain their productivity for fuelwood for many decades.

From now on, the demand for pinyon-juniper fuelwood will probably continue to increase. Generally speaking, any pinyon-juniper woodland that is being harvested for fuelwood should be placed under a management system designed to provide fuelwood on a continuing basis at or near the maximum rate that the site is capable of producing.

For the most part, it is the old high-graded stands that contain enough fuelwood for economical harvest at present. These stands often contain old poor-form trees and a disproportionally high percentage of juniper. Cutting systems for these stands should be designed to improve tree-form and species composition as well as maintaining an adequate growing stock. In most cases, the individual tree selection harvesting method should be used to maintain fuelwood productivity. Stand basal area should not be reduced below 40 ft^2/acre (9 m^2/ha) and spacing between leave trees should not exceed 30 ft (9 m) to avoid reduction in future fuelwood yields. If the best nut-producing pinyons are left uncut, the long-term yields of nuts would be increased in many cases.

Harvesting operations should be carefully managed to minimize damage to residual vegetation, including advanced reproduction and shrubs. Slash burning should be limited to that needed to reduce fire hazard to acceptable levels. Slash burning damages residual vegetation and results in loss of nitrogen and other nutrients. Lopped and scattered slash provides partial shade for seedlings, reduces soil erosion, and gradually returns nutrients to the soil.

Although Christmas trees can be harvested in woodlands that are managed by the selection method, such harvesting should be closely supervised to avoid cutting trees that should be left to produce wood. As much as possible, Christmas tree cutting should be confined to younger stands that have reoccupied old burns and other cleared areas.

Forage production would usually increase in stands harvested by the individual tree selection method, but the increases would usually be small and of short duration because roots of the residual stand reoccupy the soil mass previously utilized by the harvesting trees. In those localities where substantial increases in forage production are required, patch cutting should be used. The patches should be no larger than 5 acres (2 ha) and should be irregularly shaped to reduce visual impact and to increase edge effect. Clearcutting of larger areas is not appropriate in pinyon-juniper woodlands unless the management objective is type conversion to livestock range.

Custodial Management

Where it is not practical to manage for sustained yield of either wood or forage, management becomes custodial in nature. The bulk of pinyon-juniper woodlands are presently under custodial management and most are likely to remain so for a long time because slopes are too steep or potential productivity is too low for intensive management. Under custodial management with fire protection, forage for livestock and wildlife would continue to decline but most other values including fuelwood and nut production, watershed stability, recreation, and esthetic values would remain constant or improve. Wood production on many sites could be expected to continue until enough volume accumulates to make sustained yield management feasible.

Most pinyon-juniper woodlands have been protected from fire for more than 60 years. A "let burn" policy is an alternative worth considering because fire protection is expensive and because recurring fires were probably quite common in pinyon-juniper woodlands before fire protection and are a natural part of the ecosystem. If wildfires were allowed to burn in appropriate stands, we might expect increased forage for livestock and wildlife and improved habitat for some wildlife species. Areas where fire protection will be suspended should be carefully selected. Many areas have not burned for so long that they will not respond favorably to burning because the understory is badly suppressed, soil seed reserves are depleted, and many desirable species have been eliminated from the stand. Such areas would definitely require reseeding after fire which may cost more in relation to net benefits obtained than continous fire protection.

CONCLUSIONS

Type conversion in pinyon-juniper woodlands should be limited to those areas where costs of conversion, maintenance, and lost benefits are exceeded by resultant benefits after taking probability of failure into account. Because fuelwood is becoming increasingly valuable, range improvement may not be practical in areas presently producing appreciable amounts of fuelwood. Range improvement efforts in pinyon-juniper woodlands will generally be more efficient if applied to maintaining and improving existing conversion areas, to preserving natural openings and recent burns within the pinyon-juniper woodlands, and to preventing invasion into adjacent communities. Prescribed burning and individual tree control methods will usually be the best methods for accomplishing these objectives.

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ECOLOGICAL CHANGES OF GRAZED AND UNGRAZED

PLANT COMMUNITIES

Kenneth D. Sanders and Annette S. Voth

ABSTRACT

Foliar and ground cover were compared periodically between grazed and ungrazed plots from 1931 to 1977 on a sagebrush-bunchgrass rangeland in the Boise National Forest. There was consistently more ground cover on the grazed plots after 46 years than on the ungrazed plots. The differences in foliar cover between the grazed and ungrazed plots were variable from one sampling date to another and did not show any clear trends. While there were changes in vegetation over time, apparently the rate of succession was the same on both treatments.

INTRODUCTION

With today's high costs for range rehabilitation, land managers must decide whether to use artificial means or to rely on natural succession to restore severely disturbed or poor condition rangelands. The rate of secondary succession may determine which approach is most efficient. While we recognize that secondary succession is extremely slow in the Intermountain Region, site specific data are meager.

In the late 1800's and early 1900's, heavy use of rangelands on the Boise National Forest led to deteriorating range conditions. The problem was recognized in the 1920's, and action was taken to remedy the situation. In addition to controlling livestock grazing, range scientists initiated a long-term study of natural revegetation processes.

Between 1927 and 1931, several livestock exclosures were constructed on various sites. In 1931 a number of permanent plots were established inside and outside the exclosures to study secondary succession. The plots were studied almost yearly from 1931 to 1940 and again in 1955 and 1977. Vegetation changes within the exclosures during the 46 year period were reported by Voth (1979). The data was limited in several ways. Some exclosures had not been adequately maintained and others had occasionally been used as livestock holding pens. In some instances, study plots outside the exclosure were in a different habitat type than those within the exclosure. Only two of the exclosures provided a valid comparison between grazed amd ungrazed plots and are reported herein.

LITERATURE REVIEW

Costello and Turner (1941) compared 139 areas protected from grazing for 30 years with adjacent grazed areas. Most of the areas were located in the short grass plains, but a few were in vegetation similar to that of the Intermountain Region. In general, they found a greater density of grass plants in the protected areas than in the grazed areas, but found little difference in the density of browse species. Low palatability plants contributed 36 and 49 percent density, respectively, on protected and grazed areas. High palatability plants constituted 64 and 51 percent density on protected and grazed areas, respectively. This small difference after 30 years indicates a slow rate of succession. Density and percent density are in reference to cover, as estimated in square foot density.

Robertson (1971) studied a depleted area in a big sagebrush-Sandberg bluegrass range type in northern Nevada that had been protected from grazing for 30 years. A 20-acre (8-ha) exclosure was established in 1939 and basal cover by species was recorded. Resampling in 1979, he found an increase in cover of over 60 percent. Thurber needlegrass increased in cover over 700 percent, squirreltail increased nearly 300 percent, and Sandberg bluegrass stayed about the same. Perennial forb cover increased by 85 percent, while annual forbs decreased. Big sagebrush and horsebrush decreased in height by 3 inches (7.6 cm). The area bordering the exclosure was cleared and seeded to crested wheatgrass in 1968. The seeded area was producing more than four times the amount in the exclosure, 926 vs 199 lbs/acre (1038 vs 223 kg/ha), and the forage was more accessible. Robertson concluded that while a long rest can improve forage cover on a depleted sagebrush range, obviously superior results can be obtained by brush control and seeding.

McLean and Tisdale (1972) drew some interesting conclusions from a 30-year study of exclosures in rough fescue and ponderosa pine zones of British Columbia. They estimated it takes 20 to 40 years for poor condition ranges in these zones to re-

Kenneth D. Sanders is Extension Range Specialist for the University of Idaho, Moscow, and is stationed at Twin Falls, Idaho. Annette S. Voth is a former graduate student, Department of Range Resources, University of Idaho, Moscow, and is currently farming at Peabody, Kansas.

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cover to excellent condition when fully rested. Most of the improvement occurred in the last 10 years with little change in plant composition the first 10 years. They concluded that the time required for improvement is related to soils, climate, competing species and available seed source. The longer time period required to progress from poor to fair than from fair to good has an important implication for management. Long periods of complete rest are not an economically acceptable form of range rehabilitation. They suggested two alternatives: (1) develop a grazing system that will improve range condition, or (2) reseed the area.

Other studies in the Intermountain Region have also concluded that succession following protection from grazing is extremely slow or nonexistent (Rice and Westoby 1978). Harness and West (1973) found that changes following 15 years of protection from grazing in big sagebrush-squirreltail sites were too slow to rely simply on natural revegetation. Tisdale, Hironaka and Fosberg (1969) pointed out that because of its ecological position as a dominant, sagebrush competes strongly with herbaceous understory plants. Once the herbaceous vegetation has been wholly or nearly eliminated and sagebrush has taken over, recovery of the understory may be delayed indefinitely. Such vegetation has shown little improvement, even after 25 to 30 years of protection from grazing.

STUDY AREA DESCRIPTION AND METHODS

Description

The study area is located approximately 50 miles (80 km) east of Boise and 50 miles north of Mountain Home, Idaho or midway between the Arrowrock and Anderson Ranch Reservoirs. It is characterized by highly dissected slopes and deep V-shaped valleys, with exclosure elevations ranging from 4,000 to 5,200 feet (1 200 to 1 600 m). The soils are derived from granitic parent material and are generally coarse textured, loose in structure and highly erodible. The average annual precipitation in the study area varies from 16 to 20 inches (40 to 50 cm), with 70 percent falling during the winter and spring months.

The two exclosures will be referred to as Lester Creek and Wood Creek. However, the Wood Creek exclosure has some plots located on south slopes and others on less harsh aspects. The south slope plots will be referred to as Wood Creek South and the remainder as Wood Creek.

Lester Creek was identified as an *Artemisia vaseyana*/*Symphoricarpos oreophilus*/*Agropyron spicatum* habitat type, as described by Hironaka, Fosberg and Winward (1983). All Wood Creek plots were identified as an *Artemisia vaseyana*/*Agropyron spicatum* habitat type. However, the Wood Creek South plots are in the drier spectrum of this type.

The grazing history outside the Lester Creek exclosure is well documented, but from 1931 to 1955 records of use outside the Wood Creek exclosure are almost impossible to interpret (Voth 1979). Prior to the start of the study, grazing in both areas was unregulated, with season-long use by cattle, sheep and horses. Although numbers of animals utilizing the range at that time are not known, it is known that heavy use occurred until at least 1922 on the Lester Creek area and 1931 on the Wood Creek area.

In 1922, use in the Lester Creek area was restricted to cattle and numbers were reduced dramatically. From 1926 to 1970, the stocking rate averaged approximately 2 acres per animal unit month (1 ha/AUM). The area had nonuse from 1970 to 1976. Cattle returned to the area in 1976 and 1977, again at a rate of 2 acres/AUM, and a rest-rotation grazing system was initiated in 1977.

From 1931 to 1947, the Wood Creek area was primarily a sheep allotment. In 1948, use was converted to cattle and remained so through 1977. The degree of use is difficult to establish, but it is known that cattle made season long use from 1948 to 1965. A deferred-rotation grazing system was used from 1965 to 1972, when a rest-rotation system was implemented. At the time the exclosure was established, this site represented the most severely depleted portion of the study area.

Methods

A variable number of 16.4 x 16.4 ft (5 x 5 m) plots were permanently located inside and outside the exclosures in 1931. Eight plots were located at both Lester Creek and Wood Creek South, with half inside and half outside the exclosures. Only two plots were located at Wood Creek. The plots were subdivided by tape into five 3.3 ft (1 m) wide strips.

Foliar cover by species was recorded in each strip. Measurements were made of the projected area of individual plants compressed to 10/10ths density. The same technique was used in 1977 as earlier in the study, to compare change through time. Cover values were summarized by life form. In 1977 only, percent vegetation, litter and bare ground were estimated. In each 9 ft^2 (1 m^2) plot, 10 points were randomly selected and a record made of the category first encountered. The number of hits in each category was then summed for the entire plot and the percent of each category calculated.

RESULTS AND DISCUSSION

Contrary to what might be expected, the grazed plots in 1977 consistently had a higher percent plant and litter cover than those plots protected from grazing for 46 years (table 1). However, an examination of foliar cover by life form (table 2) does not show such a clear-cut difference. Foliar cover of perennial grasses and forbs was greater in the grazed than in the protected plots at Lester Creek, but just the opposite at the two Wood Creek sites. No difference was detected in percent foliar cover of annual grasses or forbs between the grazed and ungrazed plots at Lester Creek or Wood Creek. The Wood Creek South grazed plots had 5 percent less annual grass cover but 2 percent greater annual forb cover than the ungrazed plots. Shrub foliar cover differences were variable among the three plot groups.

Table 1. Average percent ground cover of grazed and protected plots within plot groups as estimated in 1977.

Plot Group	Ground Cover: Vegetation	Litter	Bare Ground
	Percent		
Lester Creek			
grazed	48	24	29
protected	38	20	39
Wood Creek South			
grazed	22	45	33
protected	20	48	32
Wood Creek			
grazed	19	25	55
protected	15	21	65

There were no obvious trends in foliar cover differences between grazed and ungrazed plots during the 46-year study (table 2). Voth (1979) reported that all protected plots in the Lester Creek and Wood Creek groups showed clearly identifiable directional change between 1931 and 1977. The largest changes occurred between 1940 and 1955 and the least change in the first nine years. The Wood Creek South protected plots showed little change during the 46 years, with one plot remaining the same throughout. Apparently the rate of secondary succession was the same for the grazed as the ungrazed plots in the three plot groups.

While the vegetation changed through time (Voth 1979), the patterns of change in foliar cover following exclusion of livestock did not noticeably differ from the patterns of change occurring under moderate but continued grazing. This lack of a difference may be, in part, due to an experimental design and methodology that was not sensitive enough to detect differences. Production or frequency measurements would probably have been more satisfactory.

Table 2. Average percent difference in foliar cover by life form between grazed and protected plots within plot groups as estimated in each of five years. A plus (+) indicates greater cover on the grazed plots than the protected and a minus (-) less.

Life form within Plot Group	Foliar Cover: 1931	1934	1940	1955	1977
	Percent				
Lester Creek					
Perennial Grasses	+ .5	0	- .4	+ .5	+ 2.5
Perennial Forbs	+ 1.6	+ 2.0	+ .9	+ 5.6	+ 3.9
Shrubs	+ .3	- .3	- .4	- 1.2	- 3.0
Biennials	+ .1	- .1	0	0	- .2
Annual Grasses	0	0	0	0	0
Annual Forbs	0	0	0	+ .1	- .1
Total Difference	+ 2.5	+ 1.6	+ .1	+ 5.0	+ 3.1
Wood Creek South					
Perennial Grasses	0	- .2	- .2	- .7	- .7
Perennial Forbs	0	- .1	- .2	- .9	- .5
Shrubs	0	0	0	0	0
Biennials	- .1	0	0	- .1	- .2
Annual Grasses	- 1.0	+ .4	0	- 6.3	- 4.6
Annual Forbs	+ 4.1	- .2	+ .4	+ 6.3	+ 2.0
Total Difference	+ 3.0	- .1	0	- 1.7	- 4.0
Wood Creek					
Perennial Grasses	+ .2	- .1	+ .5	+ .5	- 1.3
Perennial Forbs	+ .1	+ .2	+ .2	- .8	- 1.7
Shrubs	0	0	+ .1	0	+ 1.2
Biennials	0	+ .2	+ .1	+ .2	- .4
Annual Grasses	- 1.0	0	0	- .1	0
Annual Forbs	+ .1	- .1	+ 2.3	+ .9	- .2
Total Difference	- .6	+ .2	+ 3.2	+ .7	- 2.4

If it is assumed that, indeed, no difference exists between grazed and protected areas, what implications does this have for management? First, the moderate levels of grazing instituted at the start of the study may have been well within the tolerances of the perennial grasses and thus acted as protection. It is also possible that an advantage gained from trampling seed into the ground compensated for the stress of defoliation due to grazing. A third possibility is that inadequate time for a significantly greater change in the protected plots had elapsed.

The slow rate of change between 1931 and 1940 in the protected plots reported by Voth (1979) was attributed to a drought during this period. Severe soil erosion had occurred prior to 1931 and probably continued for a few years after reductions in grazing pressure. Any loss of soil would have affected the re-establishment of vegetation. McLean and Tisdale (1972) also reported the slowest rate of change during the first 10 years of protection from grazing.

The more mesic Lester Creek plots had the highest ratio of perennial to annual grass foliar cover. The most harsh site, Wood Creek South, had the lowest ratio of perennial to annual grass cover, and thus is more likely to have a greater year-to-year fluctuation in foliar cover. This may explain the variability and lack of clear-cut differences between grazed and ungrazed plots in the Wood Creek and Wood Creek South sites.

CONCLUSIONS

Several conclusions can be drawn from this study and other similar studies reported in the literature. 1) Secondary succession of rangelands in the Intermountain Region is extremely slow, requiring 20 to 40 years even when completely protected from grazing. In some instances they may never improve, until additional soil development occurs. 2) The time required for improvement is related to soils, climate, competing species and the availability of a seed source. 3) The way a plant is grazed may be more important than whether it is grazed or not. The physiological needs of the plant may be just as effectively met through some type of grazing system as through complete rest. 4) Annual grass ranges may never come back to perennials without first removing the competition and reseeding to perennial grasses. 5) Other factors besides livestock grazing can cause retrogression of a plant community, such as insects, wildlife, fire and extended drought. Managers should determine the cause of retrogression before trying to restore rangelands through livestock manipulation. 6) Long periods of complete rest are not economically acceptable to livestock operators. We are left with two choices: either initiate a grazing system that meets the desirable plants' needs and accept a stable or very slow improvement in condition, or rehabilitate the area by spraying, burning, plowing and/or reseeding. The range manager must determine which alternative is most cost-effective.

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MANAGEMENT OF SEEDED RANGELAND TO MAINTAIN FORAGE PLANTS

Lee Sharp

ABSTRACT: Physical characteristics of the management environment must be understood if the forage plants on artificially seeded rangelands are to be maintained. Goals and objectives established for the use of these rangelands must be within the biological capabilities and limitations of the species seeded. Because of the many physical and biological variables operating in the management environment, the manager must be flexible in adapting to these variations if the forage plants are to be maintained.

INTRODUCTION

The U.S. Department of Agriculture through its Division of Agrostology began artificial seeding trials on rangeland from 1895 to 1900 (Stoddart and Smith 1934). The Forest Service began seeding studies in 1907 (Sampson 1913) and continues this to the present. The early trials tested the feasibility of seeding in restoring depleted and deteriorated rangeland. Because of the limited success with these trials there was little opportunity to examine management practices to maintain the forage species.

Many of the early seeding trials were unsuccessful for a variety of reasons. Sufficient seed for planting was available only for a limited number of species. Equipment for clearing brush and preparing the seedbed was primitive and, because of the small size of seedings, rodents prevented successful establishment of the seedlings that emerged.

Increased interest in artificial seeding of rangeland arose during the depression and drought years of the 1930's. Concern for land use and abuse, the government land purchase program, and make-work programs for the unemployed also contributed to the interest.

C.L. Forsling (1945), Director of the Grazing Service, commented that, "The forage cover, and hence the grazing capacity, can be improved within justifiable economic limits on literally millions of acres of the Federal range by mechanical treatment and reseeding." The 1948 Yearbook of Agriculture, titled Grass, said, "Full restoration of much of the rangeland in need of improvement will require more than better grazing management" (Pearse and others 1948). An estimated 80 million acres (32 million ha) of rangeland had been so badly depleted that artificial seeding would be required if these lands were to be restored in a generation.

Funding for such activities increased dramatically during the 1950's and several million acres were seeded to adapted species. The predominant species seeded were desert wheatgrass (*Agropyron desertorum*) and crested wheatgrass (*Agropyron cristatum*). The search for new species and varieties expanded and research on seeding methods and techniques improved the chances for success. Concern was expressed that the success of the seeding program would cause managers to substitute seeding for management. Numerous studies were undertaken, however, to improve the management of artificially seeded rangelands.

Vallentine (1971) lists 80 species of perennial plants commonly seeded on range and other perennial pasture. Over half (58 percent) are introduced species and nearly three-quarters (74 percent) belong to the grass family. Additional species and new varieties are constantly being tested for use in rangeland seeding programs. Because of the large number of species used in seeding rangelands, only general principles for their management will be discussed.

Simple guides to management have a low probability of success in semi-arid environments. If objectives of management are to be achieved, a flexible adaptive procedure will be required.

MANAGEMENT CONSIDERATIONS

By definition and implication, management is the direction, control, or handling of a thing or resource to accomplish some desired or specified end or goal. In artificial seeding, the goal or objective is maintenance of the forage plants or seeded species. Achieving this goal also accomplishes a more fundamental purpose of rangeland management: providing for soil stability. If maintaining the forage species to assure soil stability were the only goal, management would appear to be relatively simple. Preventing any use of the seeded stand by grazing animals or other disturbing influences would accomplish the stated goal. However, other or auxiliary objectives may be accomplished as well as the primary goal. Other or auxilary objectives include: increased livestock production, improvement of off-site range conditions, improved wildlife habitat, increased efficiency of livestock enterprises, or a combination of these. It should be noted, however, that lack of some degree of defoliation may cause plants to lose vigor and decline in amount. Grazing often stimulates

Lee Sharp is Professor of Range Resources at the University of Idaho, Moscow, Idaho.

tillering, and seedling establishment is enhanced when animals press seeds into the ground through trampling.

The majority of rangeland that has been seeded in the west includes livestock grazing in the objectives for management. Where providing forage for grazing animals as an important auxiliary objective, it is the manipulation of grazing animals that will be of primary concern in maintaining the forage species. This of course assumes that the seeded species is or are adapted to the physical and biological conditions of the seeded area. The following discussion assumes that livestock grazing is an important objective in managing seeded vegetation.

CHARACTERISTICS OF THE MANAGEMENT ENVIRONMENT

Rangelands include an array of conditions that stretch from arid and semi-arid shrublands, shrub-grasslands, and grasslands to subhumid and humid grasslands, mountain meadows, and forest lands. Each of these larger units is composed of a wide variety of habitat types or sites that have their own physical and biological characteristics.

Many of the species used in artificial seeding of rangelands are adapted to a variety of habitat types and/or range sites. Because the habitat types and sites, as well as the broader classification units, differ in soil characteristics, precipitation, temperatures, and other physical characteristics, we would not expect the seeded species to respond to management in the same way throughout the range of conditions where the species is adapted.

Ranch operations vary among locations and have different needs for seeded areas as to season of use and intensity of grazing. Other land use values may vary over the area adapted to a plant species and thus add different dimensions to the management environment.

BIOLOGICAL CHARACTERISTICS

A decisionmaker must know the consequences of defoliation on plant growth, reproduction, and vigor, to maintain the seeded forage species. Plants manufacture foods through the process of photosynthesis. This process requires light, water, nutrients, and chlorophyll--the green tissue in plants. Food (carbohydrates) produced during the growing season is used for growth and reproduction and for carrying on vital functions during the dormant period. Additional food must also be accumulated to provide the energy for initiation of growth the following year. Forage plants, under most circumstances, produce carbohydrates in excess of that needed for all these processes. Growth produced by this excess, but only the excess, can be harvested by grazing animals.

Knowledge of how defoliation affects the accumulation of reserve material in plants becomes a useful tool for directing animal use of an area. Generally speaking, reserve food accumulation follows a cyclic pattern of use and recharge that varies "surprisingly little among species and kind of plant" (Dahl and Hyder 1977).

Maximum storage usually occurs prior to the onset of dormancy followed by a gradual decline until growth initiates the following year. The early stages of growth draw heavily on these reserves until sufficient photosynthetic tissue develops that can provide energy for this process. Reserve material tends to accumulate at an increasing rate until flowering or seed formation, at which time there is a slowing of the rate of accumulation. Defoliation disrupts this cyclic pattern and the degree of disruption depends on the timing, intensity and frequency of defoliation. Plant species may vary in the rate and amount of photosynthate produced and consequently in the effects that defoliation has on their maintenance.

Knowing when defoliation causes the most harm, how long a species may endure criticial periods of defoliation and be restored to productivity, and the length of time required for plants to regain or restore their vigor with no defoliation, will assist the manager in developing grazing management strategies to maintain forage plants and achieve other objectives (Heady 1974).

A complication in the management of seeded stands is periodic outbreaks of rabbits, rodents, insects, and other pests. These sources of defoliation are less well controlled than livestock.

PHYSICAL CHARACTERISTICS

The most universal attribute of western rangeland environments is the extreme variability in vegetation production that exists from one location to another and during various years at the same location. Differences in climate, weather, soils, topography, and animal influences account for most of the variability.

Amount and distribution of precipitation and/or temperatures exert a strong influence on production variability at a given location. For example, annual precipitation near Malta, Idaho, from 1957 through 1968 averaged 12.5 inches (32 cm) but varied from 6.8 inches (17 cm) in 1960 to 18.4 inches (47 cm) in 1963. More importantly, in May, a critical month in the growing season, precipitation varied from 0.5 inches (1 cm) to 4.8 inches (12 cm) with an average of 2.1 inches (5 cm) during the 12 years. Production of the seeded species under these conditions varied from less than 200 lbs/acre (277 kg/ha) to over 800 lbs/acre (909 kg/ha) from 1957 to 1968. Of this variation in production, 85 percent could be explained by the amount of April-May-June precipitation.

Precipitation--amounts and distribution--is probably the most dominant factor in producing variability in semi-arid and arid environments, while temperatures may be more important in the sub-humid to humid mountain environments.

Constantly adjusting stocking rates or changing the length of the grazing period may be a means to maintain the seeded species. Such adjustments, however, may be difficult in a particular ranch operation. Carefully planned grazing systems in which the variability from year to year is mitigated may avoid sharp fluctuations in animal numbers and/or length of season.

RANCH OPERATIONAL CHARACTERISTICS

The various forage and feed resources, production practices, and needs of a particular ranch operation are generally unique for that ranch even though there may be many similarities among ranches of the same area. Various combinations of private range, Forest Service permits, state lease lands, irrigated pasture and hay lands occur among ranch enterprises. One ranch may need forage and benefit from a seeded area only in the spring, another spring and fall, or summer or winter, and some ranches may benefit from year-long use of the seeded areas.

Each of the combinations of resources may require a different management strategy. Even selection of the species to be seeded should be done in light of the characteristics and needs of the ranch enterprise. If two seeding species, for example, are adapted to the same range area and one is tolerant of early spring grazing and the other not, and if the ranch enterprise benefits most from early spring grazing, it would be foolish to plant the later developing species even though it may be more productive on the site.

COPING WITH THE MANAGEMENT ENVIRONMENT TO ACHIEVE MANAGEMENT OBJECTIVES

The many physical and biological variables operating in the management environment present a continually changing array of conditions to the manager or decisionmaker. Social, economic, and political conditions are also constantly changing and this makes the managerial problems more complex.

Our efforts to manage seeded as well as other kinds of rangeland, at least on public lands, consist of simplifying the decisionmaking process by rigidly adopting proper use levels or some standard grazing system. As Costello (1957) states, "Oversimplification leads to poor interpretation. And poor interpretation leads to poor management." Poor management may lead to loss of forage species or an underattainment of the objectives specified.

Because of the physical, biological, and other conditions associated with rangelands in general and artificial seeding rangelands in particular, the manager must expect the unexpected and be able to adapt management practices accordingly. To do otherwise may preserve the seeded stand but diminish the flow of products, values, and benefits from these lands.

What is needed is a management posture that permits and encourages flexibility to adapt to the variations in the management environment in such a way that management objectives are satisfactorily achieved. Most range managers are not ecologically dumb and will apply imaginative and innovative ways to achieve management objectives if not unduly constrained by administrative directive.

Monitoring or feedback to the manager is essential for adapting management actions. Remember, there are or may be many alternative ways of achieving the objectives of management. Public land managers need the opportunity and encouragement to use their knowledge and experience to pursue the alternatives.

Although I have no hard data to support the statement, I feel that, in general, the present management of most seeded rangeland is such that the forage plants are being maintained. However, many of the benefits that could accrue to society are not being realized because of management practices. This may be, in part, due to not establishing, through auxiliary objectives, what we wish to accomplish other than maintaining the forage stand. Because so much of the seeded acreage is federally owned, the managers or decisionmakers are federal employees. As such they do not hold property rights to the resources they manage and, consequently, they do not capture the benefits or bear the costs of their management decisions. The incentives, accordingly, may be and are likely to be different than seeded rangeland in private ownership. This is not intended as a criticism but as a condition of the management environment.

If society is to reap the full array of benefits from seeded rangelands, we need to: (1) more fully assess the capabilities and limitations of these lands for different uses and values; (2) develop alternative management strategies based on the capabilities and limitations of the seeded species; and (3) develop innovative, flexible, and adaptive management programs to capture the potential benefits.

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VEGETATION REQUIREMENTS FOR FISHERIES HABITATS

William S. Platts

ABSTRACT: This report discusses the importance of streamside vegetation to each of the four habitat components that make up the aquatic environment. The effects of changes in riparian vegetation on stream temperatures, streambank stability, stream nutrients, fish cover, and fish food are discussed. Questions are presented to help land managers make intelligent decisions concerning management of riparian vegetation.

INTRODUCTION

Geologic structure that gives shape to landforms, and in turn, to streams is measured in millions of years. Streams of the Intermountain West acquired much of their present structure during the late Pleistocene, about one million years ago. The surrounding soils developed in thousands of years and most soils are of no more than Holocene age. Plant associations around streams, however, can be measured in only tens or hundreds of years. These plant associations, especially under man's influence, are continually being modified, but because they respond to changes in management practices, the opportunity exists to convert present associations to more beneficial types. The response time of these rehabilitative changes depends on climatic conditions and soil fertility. Because the vegetative component of the fishery habitat can be manipulated quite quickly, it is often less costly and much easier to obtain immediate benefits to the fisheries through vegetation rehabilitation than through channel changes such as those gained through artificial stream structures.

Salmonids (salmon, steelhead and trout) have been on the earth in much their present form for the past million years. During this long evolutionary period, while the soils and vegetation surrounding these fish were evolving in reaction to climatic conditions, fish were also constantly adapting their life requirements to meet these changes. They did this quite successfully until the entrance of European man, the first animal they faced who was capable of quickly changing their surrounding landforms, soils, and vegetation. The transformation of many riparian-stream habitats from a natural to artificial state has already occurred over most of the West. A century of additive landuse effects has resulted in major impacts on many streams and their fisheries. The changes in the productivity and composition of riparian vegetation caused increases in stream channel widths, decreases in stream depths, increases in stream temperature, decreases in fish food supplies, and in turn a reduction in fish populations. Once deteriorated, most stream channels, unlike the riparian vegetation, are very difficult, if not impossible, to rehabilitate over the short time period.

This report discusses the importance of streamside vegetation to each of the four habitat components that make up the aquatic environment: the streamside vegetation (riparian zone), the stream channel, the water column, and the streambanks. These four components integrate as a unit to determine the quality of the aquatic habitat which in turn determines the productivity of the fishery.

VEGETATION FOR STREAMSIDE COVER

The importance of cover to fish is well documented by the many studies that found salmonid abundance declining as stream cover was reduced (Boussu 1954) and increasing as cover is added (Hunt 1969, 1976; Hanson 1977). Binns (1979) found that cover was highly significant in determining fish biomass in Wyoming streams; as cover increased fish populations increased. That often narrow fringe of bordering riparian vegetation is critical to building and maintaining the stream structure conducive to a productive aquatic habitat. This vegetation not only provides cover but buffers the stream from incoming sediments and other pollutants.

Trees, brush, grasses, and forbs each play an important role in building and maintaining productive streams. Trees provide shade and streambank stability because of their large size and massive root systems (fig. 1). As trees mature and fall into or across streams, they not only cause high quality pools and riffles to form but their large mass helps to control the grade and stability of the channel. In many aquatic types if it were not for the constant entry of large organic debris (trees) into the stream, the channel would degrade and soon flow on bedrock (fig. 2). If this were to result, there would be insufficient spawning gravel and few high quality rearing pools. Tree fall is therefore important and often a must for maintenance of stream stability. Clearing large debris from streams should only be done after thorough study.

Brush provides cover, which not only protects the streambank from water erosion, but its low

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William S. Platts is Research Fisheries Biologist at the Intermountain Forest and Range Experiment Station, USDA Forest Service, Boise, Idaho.

Figure 1.--Trees providing shade and streambank stability.

Figure 2.--Stream blowout caused by lack of channel control and stability.

overhanging height adds cover to the water column which is used by fish (fig. 3). Brush, like trees, builds stability in streambanks through its root systems and litter fall. Grasses form the vegetative mats and sod banks that reduce surface erosion and mass wasting of streambanks (fig. 4). Streamside vegetation needs high vigor, density, and importantly, species diversity, because each of the vegetative types plays an important role in forming and protecting the aquatic habitat.

Figure 3.--Brush providing streambank stability and fish cover.

Figure 4.--Grasses forming vegetative mats are effective in preventing streambank erosion.

VEGETATION FOR STREAMBANK STABILITY

Behnke (1977) states that the elimination of streamside vegetation and the caving in of overhanging streambanks by animals are the principal factors contributing to the decline of native trout populations in western streams. There is nothing new in streambanks eroding or collapsing, as these processes have been going on since banks were first formed by such events as glaciation, floods, drought, debris flows, and ice flows. This natural surface erosion and mass wasting of streambanks, however, usually occurred over prolonged time and in equilibrium with bank rebuilding processes. In other words, as banks were naturally being eroded there were just as many banks being built. During the past century we have upset this state of equilibrium by altering the banks much faster than they can be rebuilt.

Streambanks bordering small streams (stream order less than 6) provide the habitat edges or niches needed to maintain high fish populations. Fish are often adapted to this habitat interface because stable, well-vegetated streambanks provide cover, control water velocities and temperatures, and supply terrestrial foods. The condition of the streambank often governs the water depths and velocities the fish must live in.

Streamside vegetation protects streambanks by reducing the erosive energy of water, by trapping sediments to maintain the streambank, and by protecting the streambank from damage by ice flows, debris flows, and animal trampling. Removal of this vegetation exposes the soils to direct erosion from rain or surface runoff. During floods, the high stream velocities not only transport high amounts of bedload sediment, but they also tend to lay down the flexible stream side vegetation, such as willows and grasses, into mats that hug the streambank. These mats reduce the water velocity along the streambank face causing sediments to settle out and become part of the banks. This deposition is usually higher on the convex bank forms (usually found on the inside of meanders) than the concave bank forms which are the types that are usually being eroded the fastest. This deposition of sediments into the vegetative mats contributes fertilizer to the streambank soils and increases plant production and vigor. A compact mass of streambank vegetation can contribute substantially to the acquisition of sediments needed to build and maintain productive streambanks.

Streams of the Intermountain West are usually icebound in the winter. When winter "chinooks" or spring thaws arrive, this ice breaks up and starts to drift. Furthermore, when the stream is icebound, and especially during periods of heavy anchor ice, the stream often leaves its original channel and starts forming new channels. Where streamside vegetation is insufficient, there is no protective mat and bank erosion occurs. This bank erosion accelerates under certain grazing systems, and under high grazing intensities that eliminate the protective mat.

Grazing strategies, such as continuous grazing, that provide for late summer or fall grazing, reduces the streambank cover and exposes the soils directly to the ice or high channel flows (fig. 5). Rest rotation strategies that graze early one year, late the next, and rest the third, can leave this vegetative mat in fair to good condition on two out of every three years of grazing. Nevertheless, the high-intensity grazing that often occurs under rest rotation can counter this potential benefit. The condition of the vegetative mat in the late fall greatly influences the stability of the streambank.

When animals graze directly on streambanks, mass erosion from trampling, hoof slide, and streambank cave in, causes soil to move directly into the stream. When this mass movement of soil occurs, the only way the streambank can remain in the equilibrium is to trap enough sediments to rebuild itself. Because streams meander, some

Figure 5.--Continuous season-long grazing to the right and non-grazing to the left of the fence in Big Creek, Utah. Note the dramatic increase in the quantity and quality of the riparian vegetation inside the exclosure.

banks take more erosive force from water than others. When a stream meanders, the centrifugal force of the water hitting the concave bank (the outside bank of the curve) increases velocity and in turn friction on the bank. The direction of the current is not only horizontally downstream but also has vertical upwelling currents. It is important, then, that all concave banks are well vegetated with deeply rooted plants.

VEGETATION FOR STREAM TEMPERATURE CONTROL

Streamside vegetation shades the stream and reduces water temperatures (fig. 6). Solar radiation accounts for about 95 percent of the heat input into Intermountain West streams during the midday periods in mid-summer. Summer stream temperatures have probably increased in Intermountain West streams over the past century, as streamside vegetation has been reduced. This could be part of the reason for a gradual shift from game fish to less desirable non-game fish in many of the streams. Many non-game fish tolerate higher stream temperatures. In the West, streams that have lost their riparian vegetation or have had a change in riparian plant forms (e.g., from brush to grass), are often too warm in the summer and too cold in the winter. Salmonids are a cold water fish and most stocks cease growth above 68°F (20°C). Temperature changes can affect the metabolic rate of fish, change the dissolved oxygen content in the water, and influence hatching success. Water temperature and dissolved oxygen are inversely related. As water temperature increases, dissolved oxygen concentration in the water decreases. Temperatures above 68°F (20°C) have been known

Figure 6.--A well-shaded stream.

to completely stop fish migration while temperatures above 77°F (25°C) are often lethal to salmon and trout (Reiser and Bjornn 1979).

Streams can also be too cold for successful trout survival. If winter temperatures fall low enough, anchor ice can form on the bottom of the stream. Anchor ice forms when the nights are cold and the sky is clear and the channel can radiate off its heat directly to the atmosphere. Streams with little or no vegetative canopy are very susceptible to the formation of anchor ice.

Heavy formations of anchor ice can produce a complete fish kill. Anchor ice can also reduce the water interchange in the channel substrate and thus restrict the oxygen supplied to fish eggs in the gravel.

Unusual high stream temperatures can lead to disease outbreaks, cessation of feeding, the stopping of migrations, and inhibition of fish growth. Fish have evolved to survive under the natural temperature regime in their home streams and when man modifies these ranges, the results can be devastating to the fish population.

Riparian vegetation not only intercepts and reduces the intensity of solar radiation but in so doing also provides cover in the form of shade, especially along the margins of the stream. This type of cover can be critical to good fish survival because shaded streamside areas are a preferred habitat of juvenile salmonids.

Certain types of vegetation are needed to control stream temperatures. Grasses can provide overhanging cover but their shortness makes them ineffective in intercepting the sun's rays, except in very small streams (stream order 1 and 2). The larger the stream, the higher the streamside vegetation needs to be to effectively intercept the sun's rays. In large streams (stream order 6 or larger), trees must border the stream to provide effective shadowing. In small to medium streams (stream order 3 to 5) brush is sufficient, but grasses and forbs have little effect. Claire and Storch (1979) found willow cover in an ungrazed area within a livestock exclosure provided 75 percent more shade to the stream than was found in the adjacent grazed area where willow abundance was reduced.

Herbicide spraying, road construction, logging, clearing, and conversions of brush habitats to grass and forbs by grazing, have eliminated vast areas of brushy species along streams in the Intermountain West.

VEGETATION FOR FISH PRODUCTION

Streamside vegetation provides habitat for terrestrial insects, which are an important part of the fish diet. This vegetation also provides direct organic material to the stream which makes up about 50 percent of the stream's nutrient energy supply for the food chain (Cummins 1974). Removal of streamside vegetation, therefore, can affect the diet of fish by reducing both the terrestrial and aquatic insect production (Chapman and Demory 1963). Because soils in some watersheds, especially of granitic parent material, provide insufficient nutrients to the stream, riparian vegetation becomes critical in the production of fish food by providing habitat for terrestrial insects, that fall directly into the stream. The stream detritus formed from incoming terrestrial plants is a principal source of food for aquatic invertebrates that eventually become food for fish (Minshall 1967).

Cover provides shelter and may be the most fragile and important single element affecting a fishery. Streamside vegetation closely over-hanging the water surface or entering the water provides cover. Young-of-the-year salmonids are dependent on this cover for their survival, and it needs to be maintained.

DISCUSSION

Now that the vegetation requirements for the aquatic habitat and its fisheries are better understood, land managers need to find better answers to critical questions:

1. Is my management program providing for high-quality streamside vegetation?

2. How far removed from the natural state are the riparian areas in my district?

3. What are the first indicators that the streamside vegetation is increasing or decreasing in quality and how do we measure these indicators?

4. How much and what type of vegetation is needed for streambank stability and to develop the canopy needed to control stream temperatures?

5. What vegetation types provide the best cover? The most fish food?

6. What methods are available to rehabilitate degraded riparian habitats and how long does it take?

7. What intensity and system of grazing should I use to protect riparian habitats and insure their productivity?

Managers do not ask the first question often enough. Actually, fisheries specialists should answer the question and when appropriate suggest changes in management.

It took many years for streamside environments in the Intermountain West to reach their present altered conditions. It would be erroneous to expect these environments and their streams to be quickly rehabilitated. It has been well demonstrated, however, that the streamside vegetation component of the stream habitat does respond much quicker than the other components when better management practices are applied (Platts 1981). This response, in turn, speeds up the rehabilitation of other stream components, thus giving the land manager a tool to work with in developing better streams.

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MANAGING VEGETATION FOR PRONGHORNS

IN THE GREAT BASIN

Jim Yoakum

ABSTRACT

Pronghorn densities and distribution in Great Basin rangelands are directly related to the quantity and quality of vegetation. Wild fires and prescibed burning often enhance pronghorn habitats by favorably changing the vegetation. Properly designed vegetation manipulation projects can also improve pronghorn habitats. Pronghorns benefit when tall, thick stands of shrubs are thinned to produce a low, open shrubland with an abundance of grasses and forbs. Rangeland seedings should maintain 5 to 10 percent shrubs. Mixture seedings are preferred over monocultures. The planting of forbs, such as dryland alfalfa, in rangeland seedings provides preferred forage species. Specific case histories are reviewed to describe relationships between pronghorns and rangeland improvement projects on Great Basin shrub steppes.

INTRODUCTION

Vegetation is one of the most important habitat components controlling pronghorn (<u>Antilocapra americana</u>) distribution and abundance. The quantity and quality of different plant communities affect pronghorn densities (Sundstrom and others 1973; Yoakum 1972). Therefore, the production and survival of pronghorns is directly related to how vegetation is maintained or manipulated.

This paper reviews the relationship of vegetation to pronghorns regarding: (1) forage and cover habitat requirements; (2) management objectives for forage classes, composition, and structure; and (3) recommended practices for maintaining and enhancing vegetation.

PRONGHORN REQUIREMENTS FOR VEGETATION

The pronghorn's requirements for vegetation have been identified for sagebrush-grassland steppes of the Great Basin (Yoakum 1974). Vegetation characteristics including ground cover, composition, species variety, succulence, and structure were described. It was pointed out that too much or too little of any one of these vegetation characteristics could limit pronghorn densities. Pronghorn forage needs and plant structure requirements are specific and critical.

Jim Yoakum is a Wildlife Biologist with the USDI Bureau of Land Management, at the University of Nevada, Reno

Forage

An adult pronghorn needs approximately 2 pounds (.90 kg) of air-dry forage per day (Severson and others 1968). This forage must be from plant species that are palatable to pronghorns in order to provide nutrition for survival and reproduction (Stoszek and others 1978).

There have been numerous food habit studies of pronghorns in the Great Basin (Mason 1952 for Oregon; Yoakum 1958 for California, Idaho, Nevada, and Oregon; Beale and Smith 1970 for Utah; and Hansen 1982 for Nevada.) These reports substantiate that pronghorns are opportunistic herbivores selecting the most palatable and succulent forage throughout the year. Pronghorns forage on at least 10 species of grasses, 70 species of forbs, and 20 species of shrubs in the Great Basin, using about 7 percent grasses, 22 percent forbs, and 71 percent shrubs on a year-long basis (Yoakum 1958).

Unfortunately, few food habit studies have related pronghorn diets to forage available. Such comparisons are needed to analyze plant preferences and competition with other herbivores, and for managers to allocate vegetation among the herbivores on a rangeland. Recently, Hansen (1982) completed a thorough, year-long study in northwestern Nevada in a low sagebrush community. He found the pronghorns consuming nearly equal proportions of forbs (46 percent) and shrubs (45 percent), and 5 percent grasses. This was the highest use of forbs on a year-long basis reported in the Great Basin. This high use of forbs was comparable to diet studies for the grassland biome, e.g., 54 percent in Colorado (Hoover and others 1959); 70 percent in New Mexico (Russell 1964); 76 percent in Kansas (Hlavachick 1968); and 68 percent in Texas (Roebuck 1982). Roebuck's statement "Use of shrubs occurred only when forbs were not available ..." documents pronghorn preference for forbs.

Cover

Vegetation characteristics of pronghorn fawn bedsites were documented in Idaho (Autenrieth 1976) and Montana (Pyrah 1974). Both studies identified tall sagebrush habitats as important bedsites for fawns. However, Beale and Smith (1973) in Utah, Barrett (1978) in Alberta, Bodie (1979) in Idaho, and McNay and O'Gara (1982) in Nevada did not reach this same conclusion. Beale and Smith (1973) and Bodie (1979) found high predation on fawns in tall shrublands.

The habitat requirements of pronghorn fawns require further study. Tall shrubs may provide important protection cover for fawns in some biomes, but not in others. For example, shrubs often comprise less than 5 percent of vegetative cover in the grasslands yet grasslands support the highest pronghorn densities in North America (Yoakum 1968).

MANAGEMENT PROCEDURES

Because vegetation is used daily by pronghorns, and is one of the most important habitat components, there is need to document the objectives and practices of managing vegetation for the pronghorn's welfare. I have previously identified four management objectives (Yoakum 1980):

1. Initially inventory vegetation quantity and quality and follow-up periodically with monitoring studies.
2. Compare the quantity and quality of vegetation provided by a site with pronghorn habitat requirements.
3. When the vegetation on a site provides high quality pronghorn habitat, then by design, maintain these quality conditions.
4. Improve habitats which have deteriorated, or which lack pronghorn habitat requirements.

Forbs

Forbs are preferred year-round forage; their presence in the plant community is a habitat requirement. Managers allotting forage to different herbivores should avoid or alleviate severe competition for forbs which pronghorns need to subsist. Managers manipulating vegetation can encourage growth of native forbs. Livestock grazing systems can be designed recognizing that forb seeds generally mature later than grass seeds. Where rangelands are reseeded, use mixtures of seeds that include several species of forbs. Compared to 20 years ago, many forb seeds are readily available at reasonable prices.

Shrubs

Shrubs are an extremely important component of pronghorn habitats, particularily in the Great Basin. The availability of shrubs for forage during severe winters has been directly linked to pronghorn survival (Bayless 1969; Barrett 1982). Sagebrush (Artemisia sp.), bitterbrush (Purshia tridentata), and rabbitbrush (Chrysothamnus spp.) are especially important to pronghorns in the Great Basin. These plants should not be eliminated from pronghorn rangeland. Illegal spraying of sagebrush on public lands in Wyoming resulted in an administrative law decision requiring the appellant to replant sagebrush for wildlife (Diamond Ring Ranch, IBLA 73-48, August 17, 1973). Rabbitbrush is considered an undesirable forage plant for livestock; however, it is a highly preferred forage for pronghorns. Therefore, it should be protected and encouraged as a component of the natural vegetative community in pronghorn habitats.

Too much or too little of any habitat component can be benefical or detrimental to wildlife (Dasmann 1964). This is especially true for shrubs on pronghorn habitat in the Great Basin. A shortage of shrubs can reduce survival during winters when snows cover most vegetation and only shrubs protrude to provide forage, and perhaps when there are too few for adequate cover for fawns. Too many shrubs, on the other hand, impede rapid mobility from predators and compete for moisture and soil nutrients needed to produce other preferred forage species. A plant community containing 5 to 10 shrub species covering 5 to 30 percent of the ground provides optimum vegatation on pronghorn habitat.

Grasses

Although pronghorns usually do not feed heavily on grasses, shortgrass prairies east of the Rocky Mountains are noted for maintaining some of the highest pronghorn densities in North America (Yoakum 1972; Sundstrom and others 1973). These grasslands provide good forage (primarily forbs) and protection from predators (predators are easily seen; vegetation does not impede quick escape).

Grasses are important during winters as they are high in energy. Even though pronghorns do not consume large quantities, they do eat grasses each month of the year. Their preference appears to be for finer textured species such as the Poas compared to the rougher textured Agropyrons. Cheatgrass (Bromus tectorum) is readily eaten and was the only graminae found in a year-long food habit study in Oregon (Yoakum 1958). Rangelands having 20-50 percent grass ground cover were rated as preferred habitats in southeastern Oregon (Yoakum 1980).

Composition

Suitable pronghorn habitats in the Great Basin support mixtures of grasses, forbs, and shrubs. When available, each forage class is eaten in all seasons of the year. The proportion of each forage class present is a major criterion determining a habitat's degree of suitability for pronghorn occupancy (Kindschy and others 1982). In general, rangelands with about one-third each of grass, forbs, and shrubs are desirable. Total vegetative ground cover should average about 50 percent, and produce 500 to 1,000 lbs of forage per acre (563 to 1 125) kg/ha).

Structure

Plant structure is directly related to pronghorn occupancy of rangelands (Yoakum 1972). The height of vegetation appears to be a major factor. Plant communities with heights greater than 24 inches (60 cm) are less frequently occupied. This behavior may have been selected for over eons of time, since (1) predators can hide in high, thick vegetation, and (2) the pronghorn's ability to escape rapidly is impeded.

MANAGEMENT PRACTICES

Management of pronghorn habitat should be based upon a careful comparison of plant inventory and trend studies with pronghorn habitat requirements. This comparison will indicate whether to maintain vegetation in present condition or attempt to make range conditions more favorable to pronghorns. Plant community inventory and monitoring procedures were discussed in a previous paper (Yoakum 1982); greater emphasis will now be given to discussing the maintenance and enhancement of habitats.

Maintain Existing Quality Habitats

A cardinal rule of wildlife habitat management is that when an environment exists in good condition achieving its ecological site potential, then maintain that site in that good condition. The site will support the variety of wildlife species that has adapted over centuries to that ecosystem (Shelford 1963; Thomas 1979).

Following this ecological principle will not meet all management objectives, such as producing maximum numbers of pronghorns. For example, some desert-shrub communities in the Great Basin have 60 percent or more shrubs. If this is the site's natural potential, it will not support a large pronghorn population, because the site has a low carrying capacity for pronghorn. Management should not expect the site to produce more pronghorns.

When the present vegetation provides all of the biological requirements of pronghorns, then maintenance of that site is of utmost importance to maintain those pronghorns. Carrying capacity for pronghorns varies from rangeland to rangeland; always depending on the mix of pronghorn habitat requirements that a site provides. The carrying capacity of a site can change through natural plant succession as a result of a wildfire. It is because of these changes that the habitat manager must monitor sites periodically.

Pronghorns are products of their environment. If rangelands have the right combination of habitat factors, then the areas have the potential to produce maximum numbers of pronghorns. However, if a rangeland lacks just one factor, or if a factor is low in quantity or quality, then that site is limited in its ability to produce maximum numbers of pronghorns. This concept of carrying capacity is well documented for various species of big game (Russo 1964; Dasmann 1971; Caughley 1979) but it appears to be not so well understood for the pronghorn, especially on rangelands that are managed for multiple use. I repeat this basic principle of habitat management for emphasis: Recognize habitats in good ecological condition, and then by objective, maintain them. Management of such sites will provide not only for pronghorns, but also will provide natural environments for the security of other wildlife species endemic to the areas.

Enhance Habitats in Low Quality Condition

If a habitat is in good condition, it is producing its natural potential of pronghorns; therefore, manipulation of vegetation cannot be justified as a means to improve conditions for pronghorns. Only on those sites which provide inadequate vegetative conditions but which provide the right combination of other habitat factors can it be justified to manipulate vegetation for pronghorns. Pronghorns thrive on rangelands in a subclimax vegetative condition (Kindschy and others 1982). Such conditions can be the result of wildfires caused by lightning, grazing by herbivores, or vegetation manipulation. Vegetative communities in the Great Basin contain a variety of grasses, forbs, and shrubs. Range improvement projects that provide similar mixed forage classes are best suited to pronghorn requirements.

Structure Manipulation

Extensive areas of dominant (more than 30 percent plant composition), high (exceeding 24 inches [60 cm]) shrublands are low-density rangelands for pronghorns compared to similar sites with fewer shrubs and more grasses and forbs. These shrublands can be treated to make the vegetal structure more favorable for pronghorns.

Shrub control has been a major practice on western rangelands during the past 4 decades. Manipulating sagebrush with large brushland plows was one method used extensively. Sometimes up to 95 percent of the sagebrush (Vallentine 1971) was removed. However, the practice often kills other plants, especially forbs and perennial bunchgrasses used by wildlife. Chaining, another mechanical shrub control method, is accomplished by dragging a heavy anchor chain in a U-shape behind two crawler tractors traveling in a parallel direction. Chaining does not kill as many shrubs as plowing and is less damaging to native grasses and forbs.

Fire is common on rangelands and is one of nature's primary ways of developing and maintaining grasslands (Sauer 1950). Burning is the oldest known practice used by man to manipulate vegetation on grazing lands (Vallentine 1971). Accidental burns can be more deleterious than beneficial to rangeland resources; however, prescribed burning can be beneficial and economical as a habitat management technique. Prescribed burning is systematically planning the firing of lands when weather and vegetation favor a particular method of burning that can be expected to maximize benefits.

Artificial Seedings

If preferred plant species are scarce, pronghorn habitats can be seeded artificially. Scarcity of favored plants can result from repeated wild fires destroying endemic sagebrush-grassland types (Leopold 1966), and also when mining operations strip off the natural vegetation. Under such circumstances on public lands, the Surface Mining Act of 1977 requires rehabilitation of the site to its original vegetative conditions, including the replanting

of sagebrush.

Past artificial seeding programs in the western United States can be classified into three categories:

1. Single species seedings.
2. Simple mixture seedings.
3. Complex mixture seedings.

The effects of these seedings on pronghorns warrant discussion.

Single Species Seedings

Crested wheatgrass (Agropyron cristatum) has been used most frequently in single species seedings in the Great Basin. Other species of grasses have been planted, but none so extensively as crested wheatgrass.

The effect of crested wheatgrass on pronghorn populations has been not well studied to date. Reeher (1969) conducted a 2 year study on seedings, noting that pronghorns used plowed and seeded projects more than sprayed and seeded sites. Spalinger (reported in Yoakum 1980) conducted an analysis of pronghorn fecal samples collected on a crested wheatgrass seeding from Malheur County, Oregon. The samples were obtained during late winter of 1977. Although crested wheatgrass was the dominant plant in the site (frequency of 52 percent), only an estimated 2 percent was found in the pronghorn fecal samples.

Simple Mixture Seedings

When 2 to 5 species are planted concurrently, the practice is referred to as a simple mixture seeding. Often this has been the planting of 1 or more grasses and 1 or 2 forbs. Such seedings have been well used by pronghorns, especially when dryland alfalfa (Medicago spp.) was used and 10 percent or more of the native shrubs were retained.

Dryland alfalfa has been one of the most successful forbs seeded on pronghorn rangelands in southeastern Oregon (Kindschy and others 1982). In excess of 56,000 acres were planted in 36 separate seedings. Dryland alfalfa was aerially seeded over plowed sagebrush rangelands which had been drilled with crested wheatgrass. Recent analysis of 20 of these seedings disclosed that dryland alfalfa maintained 10 percent composition over a 10-year period, increasing the forb composition from 2 percent to 7 percent in seeded areas.

Another seeded grass-forb project proved beneficial to pronghorn in Bear Valley, Oregon. Forty years ago, pronghorns were not in the valley although herds occupied adjacent areas. Bear Valley was predominantly private rangelands used for grazing domestic livestock. The vegetation was changed through manipulation practices. The objective was to decrease the abundant, tall, unpalatable (to cattle) sagebrush and to plant crested wheatgrass and dryland alfalfa for livestock. This resulted in changing the vegetative structure from a dominant, high-shrub community to one of low-growing grasses and forbs with sparse stands of sagebrush. In addition, over this 40-year period the ranchers improved the habitat from a low-quality vegetative community to one highly favorable to pronghorns. Vegetation trend transects completed in 1982 disclosed that the plant composition was 57 percent grass, 47 percent dryland alfalfa, and 2 percent shrubs on treated rangelands. During this 40 year period, pronghorns first ventured into the valley for short periods and then moved back to their historic ranges. As additional acreages were manipulated and winters remained mild, the pronghorns became established in the valley year-long. The population expanded to over 600 animals within a 20-year period and supported one of the highest doe:fawn ratios in Oregon (Torland 1980).

Complex Mixture Seedings

Complex mixture seedings contain a number of different plant species (Plummer and others 1968; Yoakum and others 1980). These mixtures vary, but for wildlife habitat restoration, Plummer and others (1968) recommended mixtures to have a minimum of 6 species each of grasses, forbs, and shrubs. Plummer and his coworkers have investigated seedings for the past 30 years on over 24,000 acres of successfully treated rangelands. Their findings are the culmination of intensive research and tried and tested field results. Their publication, "Restoring Big Game Ranges in Utah," is a classic and a valuable guide for range and habitat managers concerned with restoring western rangelands. It cannot be stressed too strongly that all vegetation improvement projects should be planned in conformance with the basic principles and practices for successful range restoration advocated by Plummer and others (1968). These procedures have wide application on pronghorn rangelands throughout the west.

Complex mixture seedings serve pronghorns best because they re-establish a mixed plant community of grass, forbs, and shrubs, approximating natural conditions much more than monotypic cultures. They meet the vegetation requirements of pronghorns and many other wildlife species.

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The proceedings summarizes recent research and existing literature pertaining to the restoration and management of game and livestock ranges in the Intermountain Region. Improved plant materials and planting practices are emphasized. The series of 28 papers was presented at the Restoration of Range and Wildlife Habitat Training Sessions held in Twin Falls, Idaho, September 15-17, 1981 and in Elko, Nevada, June 22-24, 1982.

KEYWORDS: habitat improvement, range improvement, range management, plant materials, site preparation, planting techniques

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